Possible power of down-regulated offshore wind power plants

This paper proposes a method for real-time estimation of the possible power of an offshore wind power plant when it is down-regulated. The main purpose of the method is to provide an industrially applicable estimate of the possible (or reserve) power. The method also yields a real-time power curve, which can be used for operation monitoring and wind farm control. Currently, there is no verified approach regarding estimation of possible power at wind farm scale. The key challenge in possible power estimation at wind farm level is to correct the reduction in wake losses, which occurs due to the down-regulation. Therefore, firstly, the 1-second wind speeds at the upstream turbines are estimated, since they are not affected by the reduced wake. Then they are introduced into the wake model, adjusted for the same time resolution, to correct the wake losses. To mitigate the uncertainties due to dynamic changes within the large offshore wind farms, the algorithm is updated at every turbine downstream, considering the local axial and lateral turbulence effects. The PossPOW algorithm uses only 1-Hz turbine data as inputs and provides possible power output. The algorithm is trained and validated in Thanet and Horns Rev-I offshore wind farms under nominal operation, where the turbines are following the optimum power curve. The results indicate that the PossPOW algorithm performs well; in the Horns Rev-I wind farm, the strict power system requirements are met more than 70% of the time over the 24-hour data set on which the algorithm was evaluated.
An automated meal detector and bolus calculator in combination with closed-loop blood glucose control

The aim of this study is to develop an algorithm for detection of unannounced meals and an insulin bolus calculator (BC) to work in combination with the meal detector. The input of the meal detector are the continuous glucose monitoring (CGM) data and the insulin infusion rate. During daytime, the automated meal detector and the BC control the blood glucose concentration. During nighttime, a model predictive control (MPC) algorithm regulates the basal insulin rate. The meal detector detects the occurrence of a meal, estimates the amount of carbohydrate (CHO) in the meal, and estimates the meal onset time. The BC computes a bolus dose to cover the detected meal. We test the meal detector and the BC on nine virtual type 1 diabetes (T1D) patients. The meal detection algorithm, applied on the virtual patients, has a median detection delay of 40 min, detection sensitivity of 80% and a median meal onset estimation bias of 15 min. The algorithm does not have false positive.

Adaptive model predictive control for a dual-hormone artificial pancreas

We report the closed-loop performance of adaptive model predictive control (MPC) algorithms for a dual-hormone artificial pancreas (AP) intended for patients with type 1 diabetes. The dual-hormone AP measures the interstitial glucose concentration using a subcutaneous continuous glucose monitor (CGM) and administers glucagon and rapid-acting insulin subcutaneously. The discrete-time transfer function models used in the insulin and glucagon MPCs comprise a deterministic part and a stochastic part. The deterministic part of the MPC model is individualized using patient-specific information and describes the glucose-insulin and glucose-glucagon dynamics. The stochastic part of the MPC model describes the uncertainties that are not included in the deterministic part of the MPC model. Using closed-loop simulation
of the MPCs, we evaluate the performance obtained using the different deterministic and stochastic models for the MPC on three virtual patients. We simulate a scenario including meals and daily variations in the model parameters for two settings. In the first setting, we try five different models for the deterministic part of the MPC model and use a fixed model for the stochastic part of the MPC model. In the second setting, we use a second-order model for the deterministic part of the MPC model and estimate the stochastic part of the MPC model adaptively. The results show that the controller is robust to daily variations in the model parameters. The numerical results also suggest that the deterministic part of the MPC model does not play a major role in the closed-loop performance of MPC. This is ascribed to the availability of feedback and the poor prediction capability of the model, i.e. the large disturbances and model-patient mismatch. Moreover, a second order adaptive model for the stochastic part of the MPC model offers a marginally better performance in closed-loop, in particular if the model-patient mismatch is large.
Ancillary Services 4.0: A Top-To-Bottom Control-Based Approach for Solving Ancillary Services Problems in Smart Grids

Power systems are experiencing a large amount of renewable generation with highly stochastic and partly unpredictable characteristics. This change in energy production implies significant consequences related to the provision of ancillary services (AS). Current markets dedicated to the provision of AS are not able to benefit from the flexible energy resources. They also cannot cope with the new level of stochasticity, non-linearity, and dynamics of generation and flexibility. To overcome such issues and exploit the potential of flexibility resources, a new strategy is required. In this paper, by capitalizing on flexibility resources’ potential, AS 4.0 approach is proposed, which offers a comprehensive solution for the AS provision in the smart grid era.
Closed loop identification of a piezoelectrically controlled radial gas bearing: Theory and experiment

Gas bearing systems have extremely small damping properties. Feedback control is thus employed to increase the damping of gas bearings. Such a feedback loop correlates the input with the measurement noise which in turn makes the assumptions for direct identification invalid. The originality of this article lies in the investigation of the impact of using different identification methods to identify a rotor-bearing systems’ dynamic model when a feedback loop is active. Two different identification methods are employed. The first method is open loop Prediction Error Method, while the other method is the modified Hansen scheme. Identification based on the modified Hansen scheme is conducted by identifying the Youla deviation system using subspace identification. Identification of the Youla deviation system is based on the Youla–Jabr–Bongiorno–Kucera parametrisation of plant and controller. By using the modified Hansen scheme, identification based on standard subspace identification methods can be used to identify the Youla deviation system of the gas bearing. This procedure ensures the input to the Youla deviation system, and the noise is uncorrelated even though the system is subject to feedback control. The effect of identifying the Youla deviation system compared to direct subspace identification of the gas bearing is further investigated through a simulation example. Experiments are conducted on the piezoelectrically controlled radial gas bearing. A dynamic model is identified using the modified Hansen scheme as well as using Prediction Error Method identification. The resulting models are compared for different imperfect nominal models, to examine under which conditions each method should be used.

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Consumers’ Flexibility Estimation at the TSO Level for Balancing Services

Demand flexibility will be an inevitable part of the future power system operation to compensate stochastic variations of ever-increasing renewable generation. One way to achieve demand flexibility is to provide time-varying prices to customers at the edge of the grid. However, appropriate models are needed to estimate the potential flexibility of different types of consumers for day-ahead and real-time ancillary services (AS) provision. The proposed method should account for rebound effect and variability of the customers’ reaction to the price signals. In this study, an efficient algorithm is developed for consumers’ flexibility estimation by the transmission system operator (TSO) based on offline data. No aggregator or real-time communication is involved in the process of flexibility estimation, although real-time communication channels are needed to broadcast price signals to the end-users. Also, the consumers’ elasticity and technical differences between various types of loads are taken into account in the formulation. The problem is formulated as a mixed-integer linear programming (MILP) problem, which is then converted to a chance-constrained programming to account for the stochastic behaviour of the consumers. Simulation results show the applicability of the proposed method for the provision of AS from consumers at the TSO level.
Detector design for active fault diagnosis in closed-loop systems

Fault diagnosis of closed-loop systems is extremely relevant for high-precision equipment and safety critical systems. Fault diagnosis is usually divided into 2 schemes: active and passive fault diagnosis. Recent studies have highlighted some advantages of active fault diagnosis based on dual Youla-Jabr-Bongiorno-Kucera parameters. In this paper, a method for closed-loop active fault diagnosis based on statistical detectors is given using dual Youla-Jabr-Bongiorno-Kucera parameters. The goal of this paper is 2-fold. First, the authors introduce a method for measuring a residual signal subject to white noise. Second, an optimal detector design is presented for single and multiple faults using the amplitude and phase shift of the residual signal to conduct diagnosis. Here, both the optimal case of a perfect model and the suboptimal case of a model with uncertainties are discussed. The method is successfully tested on a simulated system with parametric faults.

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Estimating the Density of Fluid in a Pipeline System with an Electropump

To transfer petroleum products, a common pipeline is often used to continuously transfer various products in batches. Separating the different products requires detecting the interface between the batches at the storage facilities or pump stations along the pipelines. The conventional technique to detect the product in the pipeline is to sample the fluid in a laboratory and perform an offline measurement of its physical characteristics. The measurement requires sophisticated laboratory equipment and can be time-consuming and susceptible to human error. In this paper, for performing the online detection and separation of the batches, two methods are suggested that do not need extra equipment and are more practical. Because different petroleum products have different densities, the goal of both methods was to estimate the density of each product to detect its type. To estimate the fluid density, the first method used a recursive Kalman filtering algorithm and a model that defined the relationship among the pump's differential pressure, the volume flow rate, and the rotational speed. The second method was suggested for the cases when the measurement of pressure and flow rate are not possible but the motor current and rotational speed are directly measurable. For that purpose, first the load torque was estimated. Then, by using a model that has parameters that depend on the density and that defines the relationship between the required pump torque and its rotational speed, the parameters of this model and consequently the density of the fluid were estimated. (C) 2018 American Society of Civil Engineers.
Modelling of fasting glucose-insulin dynamics from sparse data

With the fast growth of diabetes prevalence, the disease is now considered an epidemic. Diabetes is characterized by elevated glucose levels, that may be treated with insulin. Tight control of glucose is essential for prevention of complications and patients' well-being. In this paper we model the fasting glucose-insulin dynamics in type 2 diabetes, aiming at controlling the glucose level. Relevant clinical data are typically sparse and have a sampling period much greater than the fast dynamics in the glucose-insulin dynamics in humans. We adapt a physiological model such that important slow non-linear dynamics are identifiable and test the resulting model on deterministic simulated data and sparse, slow sampled clinical data.
Modelling of glucose-insulin dynamics from low sampled data
In this paper we focus on modelling the glucose-insulin dynamics in the human body for the purpose of controlling the glucose level. Due to the fast dynamics in the glucose-insulin system compared to the natural sampling period (24 h) in a clinical situation, the model structure has to be adapted adequately. This results in a reduced order model with a nonlinear output relation. The development of the estimation methodology is based on a simulation study with a continuous time model. The resulting model structure is used for estimating the parameters of the non-linear system, representing the slow dynamics observed from the slow and sparse sampled clinical data.

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Overnight glucose control in people with type 1 diabetes
This paper presents an individualized model predictive control (MPC) algorithm for overnight blood glucose stabilization in people with type 1 diabetes (T1D). The MPC formulation uses an asymmetric objective function that penalizes low glucose levels more heavily. We compute the model parameters in the MPC in a systematic way based on a priori available patient information. The model used by the MPC algorithm for filtering and prediction is an autoregressive integrated moving average with exogenous input (ARIMAX) model implemented as a linear state space model in innovation form. The control algorithm uses frequent glucose measurements from a continuous glucose monitor (CGM) and its decisions are implemented by a continuous subcutaneous insulin infusion (CSII) pump. We provide guidelines for tuning the control algorithm and computing the Kalman gain in the linear state space model in innovation form. We test the controller on a cohort of 100 randomly generated virtual patients with a representative inter-subject variability. We use the same control algorithm for a feasibility overnight study using 5 real patients. In this study, we compare the performance of this control algorithm with the patient’s usual pump setting. We discuss the results of the numerical simulations and the in vivo clinical study from a control engineering perspective. The results demonstrate that the proposed control strategy increases the time spent in euglycemia.

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Physical-stochastic (greybox) modeling of slugging

We use state-based stochastic greybox modeling - combining physics and statistics - to model the slugging phenomenon. We extend the model of DiMeglio et al. (2010) to include random components and variable flow coefficients, providing 30 seconds prediction intervals. Altogether six models, each comprising no more than ten equations, are fitted to off-shore riser training data and then cross-validated on new data sets. We use advanced statistical methods to 1) obtain optimal parameters of a given model fitted to measurements, 2) give model predictions with uncertainty intervals, and 3) quantitatively measure the relative goodness of the extended models. These features of our reductive method are general and can be applied to any data sets. For the slugging data, simpler models are preferable over the more complex ones (although the differences are minute for practical purposes in oil and gas industry) and a high statistical significance obtained on the training data does not imply improved long term prediction on independent data. Better physical (mechanistic) models to capture slugging oscillations are needed, ultimately to develop effective control strategies.
Sensor-based detection and estimation of meal carbohydrates for people with diabetes

People with type 1 diabetes (T1D) must estimate the carbohydrate (CHO) content in meals to compute the bolus insulin correctly. To release T1D patients from the cumbersome task of counting CHO, we develop a method for detecting meals that can be used in blood glucose (BG) control. The algorithm detects a meal and estimates the meal onset and the amount of CHO. The inputs of the meal detector are the continuous glucose monitoring (CGM) data and the insulin infusion rate. We use second-order linear input-output models for insulin to subcutaneous glucose dynamics and for CHO to subcutaneous glucose dynamics. The models are converted to a linear discrete-time state-space model. A white noise double integrator models the unknown meal disturbances. The state-space model is augmented with the unknown meal disturbance (CHO ingestion rate) and a Kalman filter (KF) estimates the CHO rate (g/min). The algorithm uses two tests to announce a meal. The first test is a cumulative sum algorithm that detects changes in the KF innovation and estimates the onset of change. The second test is comparison of the estimated CHO rate with a threshold to detect a change in the rate. If both tests simultaneously detect a change, an optimal smoother estimates the meal-size. If the estimated meal-size reaches a certain amount, the algorithm announces a meal. Furthermore, we integrate a bolus calculator (BC) with the meal detector. We test the algorithm for nine virtual T1D patients. In total, the patients eat 45 meals in 13.5 days. The detection sensitivity is 93% and the detection delay has a median of 40min. The median of the meal onset estimation bias is 5min. Out of 42 detected meals, the algorithm underestimates 26 meals with a median bias of −19g, and it overestimates 16 meals with a median bias of 21g. The meal detector with the BC reduces the BG postprandial peak from 274mg/dL (unbolused meals) to 207mg/dL, and it increases the mean time in euglycemia from 50% to 79%. The meal detector combined with the BC improves glycemia for the virtual patients in this study.
Utilizing flexibility resources in the future power system operation: Alternative approaches

Future power system will experience large amount of renewable generation with highly stochastic and partly unpredictable characteristics. To safely operate power system, new Flexibility Resources (FRs) are needed to participate in the operation. Some of the new FRs are linked to the electricity system, but they are managed outside of the electrical network by other energy sectors. To this end, an Integrated Energy System (IES) is needed to exploit such cross-sectoral opportunities. On the other hand, small FRs at the distribution level exist which can play an important role in the future. To exploit existing FRs, however, new operational strategies are needed. In this paper, Transactive Energy (TE) and Control-Based Approaches (CBA) are explained as the two mainstream frameworks in relation to the future energy system operation. The paper investigates benefits and drawbacks of each framework and finally defines a benchmark to better understand the potential of these solutions for the future energy management. The paper also concludes that more comprehensive operational approaches, beyond distribution system management, are required to fulfill the upcoming requirements.

Verification of Real-Time Optimization for Multi-stage Spray Dryer Operation with Polynomial Optimization

Using polynomial optimization, we demonstrate computationally that the local optima determined by a Newton method (interior-point algorithm) for real-time optimization of multi-stage spray dryer operation are identical to the global optimum. In the first major step, we transform the optimization problem for the multi-stage spray dryer operation into a polynomial optimization problem. In this form, the global optimum can be computed by polynomial optimization. In the second major step, we compare the global optimum with the potential local optima obtained by a Newton method for three operational points of a pilot-size plant and for one operational point of an industrial plant. For each case, the Newton method is initialized at 10,000 different initial points. All the computed potential local optima computed by the Newton method are identical to the global optima computed by polynomial optimization. Consequently, based on this extensive computational evidence, we conclude that the Newton method converges to the global optima for the multi-stage spray dryer real-time optimization problem.
Condition monitoring of a rotor arrangement in particular a wind turbine
The present invention relates to a method of determining the condition of a device comprising a rotor arrangement. The rotor arrangement comprising a rotational shaft and a number rotor blades each connected at the root to the rotational shaft and extending radially from the rotational shaft. Sensors are arranged to measure for each rotor blade corresponding values of one or more of the following parameters: azimuth angle (Φ) (or a parameter related to the azimuth angle), root bending moment(s) (q), such as the edgewise and/or flapwise root bending moments. The method comprises, while the rotor arrangement rotates, recording corresponding values of azimuth angle and edgewise and flap wise root bending moments for a plurality of rotations of rotor arrangement, transforming by use of e.g. a multi blade coordinate transformation, a Park’s transformation or similar transformation the recorded edgewise and flap wise root bending moments (q) into a coordinate system rotating with the rotational shaft, thereby obtaining transformed root bending moments (qf). The method further comprising identifying periodicity in each of the transformed root bending moments, determining the condition of the rotor arrangement to be faulty, in case the one or more periodicities are identified in the transformed root bending moments.

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Adaptive control in an artificial pancreas for people with type 1 diabetes
In this paper, we discuss overnight blood glucose stabilization in patients with type 1 diabetes using a Model Predictive Controller (MPC). We compute the model parameters in the MPC using a simple and systematic method based on a priori available patient information. We describe and compare 3 different model structures. The first model structure is an autoregressive integrated moving average with exogenous input (ARIMAX) structure. The second model structure is an autoregressive moving average with exogenous input (ARMAX) model, i.e. a model without an integrator. The third model structure is an adaptive ARMAX model in which we use a recursive extended least squares (RELS) method to estimate parameters of the stochastic part. In addition, we describe some safety layers in the control algorithm that improve the controller robustness and reduce the risk of hypoglycemia. We test and compare our control strategies using a virtual clinic of 100 randomly generated patients with a representative inter-subject variability. This virtual clinic is based on the Hovorka model. We consider the case where only half of the meal bolus is administered at mealtime, and the case where the insulin sensitivity increases during the night. The numerical results suggest that the use of an integrator leads to higher occurrence of hypoglycemia than for the controllers without the integrator. Compared to other control strategies, the adaptive MPC reduces both the time spent in hypoglycemia and the time spent in hyperglycemia.

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Adaptive Unscented Kalman Filter using Maximum Likelihood Estimation

The purpose of this study is to develop an adaptive unscented Kalman filter (UKF) by tuning the measurement noise covariance. We use the maximum likelihood estimation (MLE) and the covariance matching (CM) method to estimate the noise covariance. The multi-step prediction errors generated by the UKF are used for covariance estimation by MLE and CM. Then we apply the two covariance estimation methods on an example application. In the example, we identify the covariance of the measurement noise for a continuous glucose monitoring (CGM) sensor. The sensor measures the subcutaneous glucose concentration for a type 1 diabetes patient. The root-mean square (RMS) error and the computation time are used to compare the performance of the two covariance estimation methods. The results indicate that as the prediction horizon expands, the RMS error for the MLE declines, while the error remains relatively large for the CM method. For larger prediction horizons, the MLE provides an estimate of the noise covariance that is less biased than the estimate by the CM method. The CM method is computationally less expensive though.
An Adaptive Nonlinear Basal-Bolus Calculator for Patients With Type 1 Diabetes

Background: Bolus calculators help patients with type 1 diabetes to mitigate the effect of meals on their blood glucose by administering a large amount of insulin at mealtime. Intraindividual changes in patients' physiology and nonlinearity in insulin-glucose dynamics pose a challenge to the accuracy of such calculators.

Method: We propose a method based on a continuous-discrete unscented Kalman filter to continuously track the postprandial glucose dynamics and the insulin sensitivity. We augment the Medtronic Virtual Patient (MVP) model to simulate noise-corrupted data from a continuous glucose monitor (CGM). The basal rate is determined by calculating the steady state of the model and is adjusted once a day before breakfast. The bolus size is determined by optimizing the postprandial glucose values based on an estimate of the insulin sensitivity and states, as well as the announced meal size. Following meal announcements, the meal compartment and the meal time constant are estimated, otherwise insulin sensitivity is estimated.

Results: We compare the performance of a conventional linear bolus calculator with the proposed bolus calculator. The proposed basal-bolus calculator significantly improves the time spent in glucose target (P < .01) compared to the conventional bolus calculator.

Conclusion: An adaptive nonlinear basal-bolus calculator can efficiently compensate for physiological changes. Further clinical studies will be needed to validate the results.

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An experimentally validated simulation model for a four-stage spray dryer

In this paper, we develop a dynamic model of an industrial type medium size four-stage spray dryer. The purpose of the model is to enable simulations of the spray dryer at different operating points, such that the model facilitates development and comparison of control strategies. The dryer is divided into four consecutive stages: a primary spray drying stage, two heated fluid bed stages, and a cooling fluid bed stage. Each of these stages in the model is assumed ideally mixed and the dynamics are described by mass- and energy balances. These balance equations are coupled with constitutive equations such as a thermodynamic model, the water evaporation rate, the heat transfer rates, and an equation for the stickiness of the powder (glass transition temperature). Laboratory data is used to model the equilibrium moisture content and the glass transition temperature of the powder. The resulting mathematical model is an index-1 differential algebraic equation (DAE) model with 12 states, 9 inputs, 8 disturbances, and 30 parameters. The parameters in the model are identified from well-excited experimental data obtained from the industrial type spray dryer. The simulated outputs of the model are validated using independent well-excited experimental data from the same spray dryer. The simulated temperatures, humidities, and residual moistures in the spray dryer compare well to the validation data. The model also provides the profit of operation, the production rate, the energy consumption, and the energy efficiency. In addition, it computes stickiness of the powder in different stages of the spray dryer. These facilities make the model well suited as a simulation model for comparison of the process economics associated to different control strategies.

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Comparison of three control strategies for optimization of spray dryer operation

Spray drying is the preferred process to reduce the water content of many chemicals, pharmaceuticals, and foodstuffs. A significant amount of energy is used in spray drying to remove water and produce a free flowing powder product. In this paper, we present and compare the performance of three controllers for operation of a four-stage spray dryer. The three controllers are a proportional-integral (PI) controller that is used in industrial practice for spray dryer operation, a linear model predictive controller with real-time optimization (MPC with RTO, MPC-RTO), and an economically optimizing nonlinear model predictive controller (E-NMPC). The MPC with RTO is based on the same linear state space model in the MPC and the RTO layer. The E-NMPC consists of a single optimization layer that uses a nonlinear system of ordinary
differential equations for its predictions. The PI control strategy has a fixed target that is independent of the disturbances, while the MPC-RTO and the E-NMPC adapt the operating point to the disturbances. The goal of spray dryer operation is to optimize the profit of operation in the presence of composition and ambient air humidity variations; i.e. to maximize the production rate, while minimizing the energy consumption, keeping the residual moisture content of the powder below a maximum limit, and avoiding that the powder sticks to the chamber walls. We use an industrially recorded disturbance scenario in order to produce realistic simulations and conclusions. The key performance indicators such as the profit of operation, the product flow rate, the specific energy consumption, the energy efficiency, and the residual moisture content of the produced powder are computed and compared for the three controllers. In this simulation study, we find that the economic performance of the MPC with RTO as well as the E-NMPC is considerably improved compared to the PI control strategy used in industrial practice. The MPC with RTO improves the profit of operation by 8.61%, and the E-NMPC improve.
Developing a simulation framework for safe and optimal trajectories considering drivers' driving style

Advanced driving assistance systems (ADAS) have huge potential for improving road safety and travel times. However, their take-up in the market is very slow; and these systems should consider driver's preferences to increase adoption rates. The aim of this study is to develop a model providing drivers with the optimal trajectory considering the motorist's driving style in real time. Travel duration and safety are the main parameters used to find the optimal trajectory. A simulation framework to determine the optimal trajectory was developed in which the ego car travels in a highway environment scenario, using an agent-oriented approach. The performance of the algorithm was compared against optimal trajectories computed offline with the hybrid A* algorithm. The new framework provides trajectories close to the optimal trajectory and is computationally achievable. The agents were shown to follow safe and fast trajectories in three tests scenarios: emergency braking, overtaking and a complex situation with multiple vehicles around the ego vehicle. Different driver profiles were then tested in the complex scenario, showing that the proposed approach can adapt to driver preferences and provide a solution close to the optimal solution given the defined safety constraints.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Queensland University of Technology
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Fault and meal detection by redundant continuous glucose monitors and the unscented Kalman filter

The purpose of this study is to develop a method for detecting and compensating the anomalies of continuous glucose monitoring (CGM) sensors as well as detecting unannounced meals. Both features, sensor fault detection/correction and meal detection, are necessary to have a reliable artificial pancreas. The aim is to investigate the best detection results achievable with the proposed detection configuration in a perfect situation, and to have the results as a benchmark against which the imperfect scenarios of the proposed fault detection can be compared. The perfect situation that we set up here is in terms of a patient simulation model, where the model in the detector is the same as the patient simulation model used for evaluation of the detector. The detection module consists of two CGM sensors, two fault detectors, a fault isolator, and an adaptive unscented Kalman filter (UKF). Two types of sensor faults, i.e., drift and pressure induced sensor attenuation (PISA), are simulated by a Gaussian random walk model. Each of the fault detectors has a local UKF that receives the signal from the associated sensor, detects faults, and finally tunes the adaptive UKF. A fault isolator that accepts data from the two fault detectors differentiates between a sensor fault and an unannounced meal appearing as an anomaly in the CGM data. If the fault isolator indicates a sensor fault, a method based on the covariance matching technique tunes the covariance of the measurement noise associated with the faulty sensor. The main UKF uses the tuned noise covariances and fuses the CGM data from the two sensors. The drift detection sensitivity and specificity are 80.9% and 92.6%, respectively. The sensitivity and specificity of PISA detection are 78.1% and 82.7%, respectively. The fault
detectors can detect 100 out of 100 simulated drifts and 485 out of 500 simulated PISA events. Compared to a nonadaptive UKF, the adaptive UKF reduces the deviation of the CGM measurements from their paired blood glucose concentrations from 72.0% to 12.5% when CGM is corrupted by drift, and from 10.7% to 6.8% when CGM is corrupted by PISA. The fault isolator can detect 199 out of 200 unannounced meals. The average change in the glucose concentrations between the meals and the detection time points is 46.3 mg/dL.
Fault diagnosis and condition monitoring of wind turbines

This paper describes a model-free method for the fault diagnosis and condition monitoring of rotor systems in wind turbines. Both fault diagnosis and monitoring can be achieved without using a model for the wind turbine, applied controller, or wind profiles. The method is based on measurements from standard sensors on modern wind turbines, including moment sensors and rotor angle sensors. This approach will allow the method to be applied to existing wind turbines without any modifications. The method is based on the detection of asymmetries in the rotor system caused by changes or faults in the rotor system. A multiblade coordinate transformation is used directly on the measured flap-wise and edge-wise moments followed by signal modulation. Changes or faults in the rotor system will result in unique signatures in the set of modulation signals. These signatures are described through the amplitudes and phase information of the modulation signals. It is possible to detect and isolate which blade is faulty or has been changed based on these signatures. Furthermore, the faulty component can be isolated, ie, the actuator, sensor or blade, and the type of fault can be determined. The method can be used both on- and off-line.

General information

State: Published
Organisations: Department of Electrical Engineering, Automation and Control, Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Wind Energy, Wind turbine loads & control, AF Consult
Contributors: Niemann, H. H., Poulsen, N. K., Mirzaei, M., Henriksen, L. C.
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  BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.48 SJR 0.915 SNIP 1.162
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Web of Science (2015): Impact factor 1.368
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 1.98 SJR 1.157 SNIP 1.328
Web of Science (2014): Impact factor 1.346
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.07 SJR 0.9 SNIP 1.204
Active Fault Detection Based on a Statistical Test

In this paper active fault detection of closed loop systems using dual Youla-Jabr-Bongiorno-Kucera(YJBK) parameters is presented. Until now all detector design for active fault detection using the dual YJBK parameters has been based on CUSUM detectors. Here a method for design of a matched filter detector is proposed instead, based upon the NeymanPearson criterion for optimal detector design. Furthermore alternative ways to design the excitation signal which relates to indirect identification methods are presented. Examples are given on detection of actuator faults using a simulated gas bearing for both one and multiple possible parametric faults.

General information
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Organisations: Department of Electrical Engineering, Automation and Control, Department of Applied Mathematics and Computer Science, Dynamical Systems
Contributors: Sekunda, A. K., Niemann, H. H., Poulsen, N. K.
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An Ensemble Nonlinear Model Predictive Control Algorithm in an Artificial Pancreas for People with Type 1 Diabetes

This paper presents a novel ensemble nonlinear model predictive control (NMPC) algorithm for glucose regulation in type 1 diabetes. In this approach, we consider a number of scenarios describing different uncertainties, for instance meals or metabolic variations. We simulate a population of 9 patients with different physiological parameters and a time-varying insulin sensitivity using the Medtronic Virtual Patient (MVP) model. We augment the MVP model with stochastic diffusion terms, time-varying insulin sensitivity and noise-corrupted CGM measurements. We consider meal challenges where the uncertainty in meal size is ±50%. Numerical results show that the ensemble NMPC reduces the risk of hypoglycemia compared to standard NMPC in the case where the meal size is overestimated or correctly estimated at the expense of a slightly increased number of hyperglycemia. Therefore, ensemble MPC-based algorithms can improve the safety of the AP compared to the classical MPC-based algorithms.

Application of the Continuous-Discrete Extended Kalman Filter for Fault Detection in Continuous Glucose Monitors for Type 1 Diabetes

The purpose of this study is the online detection of faults and anomalies of a continuous glucose monitor (CGM). We simulated a type 1 diabetes patient using the Medtronic virtual patient model. The model is a system of stochastic differential equations and includes insulin pharmacokinetics, insulin-glucose interaction, and carbohydrate absorption. We simulated and detected two types of CGM faults, i.e., spike and drift. A fault was defined as a CGM value in any of the zones C, D, and E of the Clarke error grid analysis classification. Spike was modelled by a binomial distribution, and drift was modelled by a Gaussian random walk. We used a continuous-discrete extended Kalman filter for the fault detection, based on the statistical tests of the filter innovation and the 90-min prediction residuals of the sensor measurements. The spike detection had a sensitivity of 93% and a specificity of 100%. Also, the drift detection had a sensitivity of 80% and a specificity of 85%. Furthermore, with 100% sensitivity the proposed method was able to detect if the drift overestimates or underestimates the interstitial glucose concentration.
Comparison of Three Nonlinear Filters for Fault Detection in Continuous Glucose Monitors

The purpose of this study is to compare the performance of three nonlinear filters in online drift detection of continuous glucose monitors. The nonlinear filters are the extended Kalman filter (EKF), the unscented Kalman filter (UKF), and the particle filter (PF). They are all based on a nonlinear model of the glucose-insulin dynamics in people with type 1 diabetes. Drift is modelled by a Gaussian random walk and is detected based on the statistical tests of the 90-min prediction residuals of the filters. The unscented Kalman filter had the highest average F score of 85.9%, and the smallest average detection delay of 84.1%, with the average detection sensitivity of 82.6%, and average specificity of 91.0%.

General information
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Diagnosis of wind turbine rotor system

This paper describes a model free method for monitoring and fault diagnosis of the elements in a rotor system for a wind turbine. The diagnosis as well as the monitoring is done without using any model of the wind turbine and the applied controller or a description of the wind profile. The method is based on available standard sensors on wind turbines. The method can be used both on-line as well as off-line. Faults or changes in the rotor system will result in asymmetries, which can be monitored and diagnosed. This can be done by using the multi-blade coordinate transformation. Changes in the rotor system that can be diagnosed and monitored are: actuator faults, sensor faults and internal blade changes as e.g. change in mass of a blade.

General information
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Organisations: Department of Electrical Engineering, Automation and Control, Department of Applied Mathematics and Computer Science, Department of Wind Energy, Wind turbine loads & control, Dynamical Systems, AF Consult
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Distributed Model Predictive Control for Smart Energy Systems

Integration of a large number of flexible consumers in a smart grid requires a scalable power balancing strategy. We formulate the control problem as an optimization problem to be solved repeatedly by the aggregator in a model predictive control framework. To solve the large-scale control problem in real-time requires decomposition methods. We propose a decomposition method based on Douglas–Rachford splitting to solve this large-scale control problem. The method decomposes the problem into smaller subproblems that can be solved in parallel, e.g., locally by each unit connected to an aggregator. The total power consumption is controlled through a negotiation procedure between all cooperating units and an aggregator that coordinates the overall objective. For large-scale systems, this method is faster than solving the original problem and can be distributed to include an arbitrary number of units. We show how different aggregator objectives are implemented and provide simulations of the controller including the computational performance.

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State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Office for Study Programmes and Student Affairs, Copenhagen Center for Health Technology, Center for Energy Resources Engineering,
Economic Model Predictive Control for Spray Drying Plants

The main challenge in cost optimal operation of a spray dryer, is to maximize the production rate while minimizing the energy consumption, keeping the residual moisture content of the powder below a maximum limit and avoiding that the powder sticks to the chamber walls. The conventional PI control strategy is simple, but known to be insufficient at providing optimal operation in the presence of variations in the feed and the ambient air humidity. This motivates our investigation of Model Predictive Control (MPC) strategies.

In this thesis, we consider the development and application of new models and MPC strategies to optimize the operation
of four-stage spray dryers. The models are first-principle dynamic models with parameters identified from dryer specific experiments and powder properties identified from laboratory tests. A simulation model is used for detailed closed-loop simulations and a complexity reduced control model is used for state estimation and prediction in the controllers. These models facilitate development and comparison of control strategies. We develop two MPC strategies; a linear tracking MPC with a Real-Time Optimization layer (MPC with RTO) and an Economic Nonlinear MPC (E-MPC). We tailor these for the spray drying process to optimize the cost of operation by adjustments to the inputs of the dryer according to the present disturbances and process constraints. Simulations show that MPC strategies improve the profit of operation by up to 9.69%, the production of powder by up to 9.6%, the residual moisture content by up to 0.114 p.p. and the energy efficiency by up to 6.06% while the produced powder is within the given quality specifications and sticky powder on the walls of the chamber is avoided. Thus, we are able to improve the cost of operation significantly compared to the conventional PI control strategy.

The proposed MPC strategies are based on a feedback control algorithm that explicitly handles constrained control inputs and uses a model to predict and optimize the future behavior of the dryer. The solution of the control problem results in a sequence of inputs for a finite horizon, out of which only the first input is applied to the dryer. This procedure is repeated at each sample instant and is solved numerically in real-time. The MPC with RTO tracks a target that optimizes the cost of operation at steady-state. The E-MPC optimizes the cost of operation directly by having this objective directly in the controller. The need for the RTO layer is then eliminated.

We demonstrate the application of the proposed MPC with RTO to control an industrial GEA MSDTM-1250 spray dryer, which produces approximately 7500 kg/hr of enriched milk powder. Compared to the conventional PI controller, our first results shows that the MPC improves the profit of operation by approximately 228,000 €/year, the product rate by 322 kg/hr, the residual moisture content by 0.166 p.p. and the energy efficiency by 1% at comparable ambient air humidity conditions. The demonstrated MPC with RTO is fully integrated in the daily operation of the spray dryer today.

Our primary objectives in the thesis are: 1) Spray dryer modeling of a smallscale four-stage spray dryer. The purpose of the models are to enable simulations of the spray drying process at different operating points, such that the models facilitate development and comparison of control strategies; 2) Development of MPC strategies that automatically adjust the dryer to variations in the feed and the ambient air humidity, such that the energy consumption is minimized, the residual moisture content in the powder is controlled within the specifications and sticky powder is avoided from building up on the dryer walls; 3) Demonstrate the industrial application of an MPC strategy to a full-scale industrial four-stage spray dryer.

The main scientific contributions can be summarized to:

- Modeling of a four-stage spray dryer. We develop new first-principles engineering models for simulation of a four-stage spray dryer. These models enables simulations of the spray dryer at different operating points with high accuracy.
- Development and simulation of control strategies. We develop two control strategies, the MPC with RTO and the E-MPC strategy. The performance of the controllers is studied and evaluated by simulation.
- Industrial application of MPC to a spray dryer. We demonstrate that our proposed MPC with RTO is applicable to an industrial GEA MSDTM-1250 spray dryer, that produces enriched milk powder.

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Economic MPC for a linear stochastic system of energy units
This paper summarizes comprehensively the work in four recent PhD theses from the Technical University of Denmark related to Economic MPC of future power systems. Future power systems will consist of a large number of decentralized power producers and a large number of controllable power consumers in addition to stochastic power producers such as wind turbines and solar power plants. Control of such large scale systems requires new control algorithms. In this paper, we formulate the control of such a system as an Economic Model Predictive Control (MPC) problem. When the power producers and controllable power consumers have linear dynamics, the Economic MPC may be expressed as a linear
program. We provide linear models for a number of energy units in an energy system, formulate an Economic MPC for coordination of such a system. We indicate how advances in computational MPC makes the solutions of such large-scale models feasible in real-time. The system presented may serve as a benchmark for simulation and control of smart energy systems and we indicate how advances in computational MPC.

Enhanced Subsea Acoustically Aided Inertial Navigation

This thesis deals with enhancing state-of-the-art underwater acoustic–inertial navigation systems that are necessary for deep water robotic operations. Throughout the project intelligent and simple operational solutions to complex real-world problems was emphasized.

Offshore hydrocarbon, oil and gas, exploration is advancing further into treacherous territories such as deeper waters and arctic region. Deep underwater navigation poses a deluge of challenges; there is no such luxury as Global Navigation Satellite Systems (GNSS) underwater. Many of these challenges have been solved, but vessel time is expensive so lots of effort is put into cutting down on time spent on all tasks. Accuracy demanding tasks such as subsea construction and surveying are subject to strict quality control requirements taking up a lot of time. Offshore equipment is rugged and sturdy as the environmental conditions are harsh, likewise should the use of it be simple and robust to ensure that it actually works.

The contributions of this thesis are all focused on enhancing accuracy and time efficiency while bearing operational reliability and complexity strongly in mind. The basis of inertial navigation, the inertial sensors are treated in a calibration study with three scenarios: factory, in-field and at-sea calibration. Factory calibration compensates for sensor misalignments during the manufacturing process and for intrinsic sensor biases etc. For calibration a precise two-axis turn-table is required. It is shown that long-term effects on inertial sensors can be calibrated and assessed in-field, on land without specialized equipment, or at sea with certain realistic limitations and assumptions.

Automatic calibration of complex multi-sensor acoustic-inertial navigation systems, using parameter estimation, is employed on unprecedented high dynamic trajectories collected from sea-trials. These are needed to increase navigation accuracy to the cm-level and beyond. The same techniques can also be used for regular navigation in order to minimize both time and human error in parameter measurements.

In a unifying litmus test, the entire body of work is applied in a novel and potentially revolutionary methodology for the most challenging of all subsea survey and construction tasks: spool piece and jumper metrology. Two distinct approaches are investigated: One seeks to eliminate acoustic seabed transponders, but keep transponders at desired survey points; the other uses a mapping sensor such as subsea lidar to simply map the area in question. Both approaches are shown to work in practice. Generating high resolution maps, as the latter approach, is how the author anticipates all subsea surveys will be conducted in the near future.
Industrial application of model predictive control to a milk powder spray drying plant

In this paper, we present our first results from an industrial application of model predictive control (MPC) with real-time steady-state target optimization (RTO) for control of an industrial spray dryer that produces enriched milk powder. The MPC algorithm is based on a continuous-time transfer function model identified from data and states estimated by a time-varying Kalman filter. The RTO layer utilizes the same linear model and a nonlinear economic objective function for calculation of the economically optimized targets. We demonstrate, by industrial application of the MPC, that this method provides significantly better control of the residual moisture content, increases the throughput and decreases the energy consumption compared to conventional PI-control. The MPC operates the spray dryer closer to the residual moisture constraint of the powder product. Thus, the same amount of feed produces more powder product by increasing the average water content. The value of this is 186,000 €/year. In addition, the energy savings account to 6,900 €/year.

Methods and Algorithms for Economic MPC in Power Production Planning

This thesis concerns methods and algorithms for power production planning in contemporary and future power systems. Power production planning is a task that involves decisions across different time scales and planning horizons. Hours-ahead to days-ahead planning is handled by solving a mixed-integer linear program for unit commitment and economic dispatch of the system power generators. We focus on a minutes-ahead planning horizon, where unit commitment decisions are fixed. Economic model predictive control (EMPC) is employed to determine an optimal dispatch for a portfolio of power generators in real-time. A generator can represent a producer of electricity, a consumer of electricity, or possibly both. Examples of generators are heat pumps, electric vehicles, wind turbines, virtual power plants, solar cells, and conventional fuel-fired thermal power plants. Although this thesis is mainly concerned with EMPC for minutes-ahead production planning, we show that the proposed EMPC scheme can be extended to days-ahead planning (including unit commitment) as well.

The power generation from renewable energy sources such as wind and solar power is inherently uncertain and variable. A portfolio with a high penetration of renewable energy is therefore a stochastic system. To accommodate the need for EMPC of stochastic systems, we generalize certainty-equivalent EMPC (CEEMPC) to mean-variance EMPC (MV-EMPC). In MV-EMPC, the objective function is a trade-off between the expected cost and the cost variance. Simulations show that MV-EMPC reduces cost and risk compared to CE-EMPC. The simulations also show that the economic performance of CE-EMPC can be much improved using a constraint back-off heuristic.

Efficient solution of the optimal control problems (OCPs) that arise in EMPC is important, as the OCPs are solved online. We present special-purpose algorithms for EMPC of linear systems that exploit the high degree of structure in the OCPs. A Riccati-based homogeneous and self-dual interior-point method is developed for the special case, where the OCP objective function is a linear function. We design an algorithm based on the alternating direction method of multipliers (ADMM) to solve input-constrained OCPs with convex objective functions. The OCPs that occur in EMPC of dynamically decoupled subsystems, e.g. power generators, have a block-angular structure. Subsystem decomposition algorithms based on ADMM and Dantzig-Wolfe decomposition are proposed to solve these OCPs. Subproblems that arise in the decomposition algorithms are solved using structure-exploiting algorithms. To reduce computation time of the EMPC algorithms further, warm-start and early-termination strategies are employed. Benchmarks show that the special-purpose algorithms are significantly faster than current state-of-the-art solvers.
As a potential application area of EMPC, we study power production planning in small isolated power systems. A critical part of power production planning in small isolated power systems is operational reserve planning. The operational reserves are activated to balance production and consumption in real-time. An EMPC scheme is presented for activation of operational reserves. Simulations based on a Faroe Islands case study show that significant cost savings can be achieved using this strategy. For efficient planning of the operational reserves, we present an optimal reserve planning problem (ORPP). The ORPP is a contingency-constrained unit commitment problem that addresses low inertia challenges in small isolated power systems.

In summary, the main contributions of this thesis are:
- A mean-variance optimization strategy for EMPC of linear stochastic systems.
- Tailored algorithms for solution of the OCPs that arise in EMPC of linear stochastic systems.
- Methods for power production planning in small isolated power; the ORPP for unit commitment and economic dispatch, and an EMPC scheme for activation of operational reserves.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Center for Energy Resources Engineering, Dynamical Systems
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Model Identification using Continuous Glucose Monitoring Data for Type 1 Diabetes
This paper addresses model identification of continuous-discrete nonlinear models for people with type 1 diabetes using sampled data from a continuous glucose monitor (CGM). We compare five identification techniques: least squares, weighted least squares, Huber regression, maximum likelihood with extended Kalman filter and maximum likelihood with unscented Kalman filter. We perform the identification on a 24-hour simulation of a stochastic differential equation (SDE) version of the Medtronic Virtual Patient (MVP) model including process and output noise. We compare the fits with the actual CGM signal, as well as the short- and long-term predictions for each identified model. The numerical results show that the maximum likelihood-based identification techniques offer the best performance in terms of fitting and prediction. Moreover, they have other advantages compared to ODE-based modeling, such as parameter tracking, population modeling and handling of outliers.

General information
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Model Predictive Control of Sewer Networks

The developments in solutions for management of urban drainage are of vital importance, as the amount of sewer water from urban areas continues to increase due to the increase of the world’s population and the change in the climate conditions. How a sewer network is structured, monitored and controlled have thus become essential factors for efficient performance of waste water treatment plants. This paper examines methods for simplified modelling and controlling a sewer network. A practical approach to the problem is used by analysing simplified design model, which is based on the Barcelona benchmark model. Due to the inherent constraints the applied approach is based on Model Predictive Control.

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Web of Science (2016): Indexed yes
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Web of Science (2014): Indexed yes
MPC control of water supply networks

This paper investigates the modelling and predictive control of a drinking water supply network with the aim of minimising the energy and economic cost. A model predictive controller, MPC, is applied to a nonlinear model of a drinking water network that follows certain constraints to maintain consumer pressure desire. A model predictive controller, MPC, is based on a simple model that models the main characteristics of a water distribution network, optimizes a desired cost minimisation, and keeps the system inside specified constraints. In comparison to a logic (on/off) control design, controlling the drinking water supply network with the MPC showed reduction of the energy and the economic cost of running the system. This has been achieved by minimising actuator control effort and by shifting the actuator use towards the night time, where energy prices are lower. Along with energy cost reduction the MPC also achieves reduction in the amount of consumed water by keeping the pressure closer to the lower pressure constraint.
On the significance of the noise model for the performance of a linear MPC in closed-loop operation
This paper discusses the significance of the noise model for the performance of a Model Predictive Controller when operating in closed-loop. The process model is parametrized as a continuous-time (CT) model and the relevant sampled-data filtering and control algorithms are developed. Using CT models typically means less parameters to identify. Systematic tuning of such controllers is discussed. Simulation studies are conducted for linear time-invariant systems showing that choosing a noise model of low order is beneficial for closed-loop performance. (C) 2016, IFAC (International Federation of Automatic Control) Hosting by Elsevier Ltd. All rights reserved.

A Bolus Calculator Based on Continuous-Discrete Unscented Kalman Filtering for Type 1 Diabetics
In patients with type 1 diabetes, the effects of meals intake on blood glucose level are usually mitigated by administering a large amount of insulin (bolus) at mealtime or even slightly before. This strategy assumes, among other things, a prior knowledge of the meal size and the postprandial glucose dynamics. On the other hand, administering the meal bolus during or after mealtime could benefit from the information provided by the postprandial meal dynamics at the expense of a delayed meal bolus. The present paper investigates different bolus administration strategies (at mealtime, 15 minutes after or 30 minutes after the beginning of the meal). We implement a continuous-discrete unscented Kalman filter to estimate the states and insulin sensitivity. These estimates are used in a bolus calculator. The numerical results demonstrate that administering the meal bolus 15 minutes after mealtime both reduces the risk of hypoglycemia in case of an overestimated meal and the time spent in hyperglycemia if the meal size is underestimated. Faster insulin and the use of glucagon will have the potential to encourage postprandial meal bolus administration and hence will not require to accurately estimate the meal size.
A Continuous-Discrete Extended Kalman Filter for State and Parameter Estimation in People with Type 1 Diabetes

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Active Fault Diagnosis in Sampled-data Systems
The focus in this paper is on active fault diagnosis (AFD) in closed-loop sampled-data systems. Applying the same AFD architecture as for continuous-time systems does not directly result in the same set of closed-loop matrix transfer functions. For continuous-time systems, the LFT (linear fractional transformation) structure in the connection between the parametric faults and the matrix transfer function (also known as the fault signature matrix) applied for AFD is not directly preserved for sampled-data system. As a consequence of this, the AFD methods cannot directly be applied for sampled-data systems. Two methods are considered in this paper to handle the fault signature matrix for sampled-data systems.
such that standard AFD methods can be applied. The first method is based on a discretization of the system such that the LFT structure is preserved resulting in the same LFT structure in the fault signature matrix as obtained for continuous-time systems. The other method is an approximation method, where the same structure is obtained for small parametric faults.

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**Adaptive Backstepping Control of Lightweight Tower Wind Turbine**

This paper investigates the feasibility of operating a wind turbine with lightweight tower in the full load region exploiting an adaptive nonlinear controller that allows the turbine to dynamically lean against the wind while maintaining nominal power output. The use of lightweight structures for towers and foundations would greatly reduce the construction cost of the wind turbine, however extra features ought to be included in the control system architecture to avoid tower collapse. An adaptive backstepping collective pitch controller is proposed for tower point tracking control, i.e. to modify the angular deflection of the tower with respect to the vertical axis in response to variations in wind speed. The controller is shown to guarantee asymptotic tracking of the reference trajectory. The performance of the control system is evaluated through deterministic and stochastic simulations including an extreme wind gust event, and the feasibility of stabilizing the tower position while maintaining the rated power output is shown.

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A smart rotor configuration with linear quadratic control of adaptive trailing edge flaps for active load alleviation

The paper proposes a smart rotor configuration where adaptive trailing edge flaps (ATEFs) are employed for active alleviation of the aerodynamic loads on the blades of the NREL 5 MW reference turbine. The flaps extend for 20% of the blade length and are controlled by a linear quadratic (LQ) algorithm based on measurements of the blade root flapwise bending moment. The control algorithm includes frequency weighting to discourage flap activity at frequencies higher than 0.5 Hz. The linear model required by the LQ algorithm is obtained from subspace system identification; periodic disturbance signals described by simple functions of the blade azimuthal position are included in the identification to avoid biases from the periodic load variations observed on a rotating blade. The LQ controller uses the same periodic disturbance signals to handle anticipation of the loads periodic component. The effects of active flap control are assessed with aeroelastic simulations of the turbine in normal operation conditions, as prescribed by the International Electrotechnical Commission standard. The turbine lifetime fatigue damage equivalent loads provide a convenient summary of the results achieved with ATEF control: 10% reduction of the blade root flapwise bending moment is reported in the simplest control configuration, whereas reductions of approximately 14% are achieved by including periodic loads anticipation. The simulations also highlight impacts on the fatigue damage loads in other parts of the structure, in particular, an increase of the blade torsion moment and a reduction of the tower fore-aft loads. Copyright © 2014 John Wiley & Sons, Ltd.

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Bihormonal control of blood glucose in people with type 1 diabetes

This paper presents a bihormonal artificial pancreas (AP) for people with type 1 diabetes (T1D) designed to provide a safe blood glucose control with minimal use of glucagon. The control algorithm employs insulin as well as glucagon to prevent hyper- and hypoglycemia. We employ a novel prediction-based activation of glucagon administration. The control algorithm consists of a Kalman filter, an insulin infusion model predictive controller (MPC), a proportional-derivative (PD) controller for glucagon infusion, and a meal time insulin bolus calculator. The PD controller is activated if the Kalman filter predicts hypoglycemia. Predictions utilize an ARMAX model describing glucose-insulin and glucose-glucagon dynamics. The model parameters are estimated from basic patient-specific data. A continuous glucose monitor provides feedback. We test the control algorithm using a simulation model with time-varying parameters available for 3 patients. We consider a simulation scenario where meals are estimated correctly as well as overestimated by 30%. The simulation results demonstrate that during normal operation, the controller only needs insulin and does not need glucagon. During unexpected events, such as insulin overdose due to an overestimated meal, the control algorithm uses glucagon efficiently to avoid severe hypoglycemia.

Closed loop identification using a modified Hansen scheme

It is often not feasible or even impossible to identify a plant in open loop. This might be because the plant contains unstable poles, or it is simply too expensive to remove the plant from its intended operation, among other possibilities. There are several methods for identifying a plant in closed loop [4], and one such method is the Hansen scheme [1]. Standard identification using Hansen scheme demands generating the identification signals indirectly. In this paper it is instead proposed to use the relationship between the Youla factorization of a plant and its stabilizing controller to directly measure the signals used for identification. A simulation example and identification of a gas bearing is given to show the method in action. Rotors supported by controllable gas bearings are open loop stable systems. However as the rotational speed is increased feedback control is necessary in order to keep the system stable. Furthermore because the dynamics of such a system depends on the rotational speed it is needed to conduct an identification while the system is part of a closed loop scheme. The authors believe the paper able to contribute towards a simpler and more direct way of identifying closed loop plants using Hansen scheme.
Comparison of Linear and Nonlinear Model Predictive Control for Optimization of Spray Dryer Operation

In this paper, we compare the performance of an economically optimizing Nonlinear Model Predictive Controller (E-NMPC) to a linear tracking Model Predictive Controller (MPC) for a spray drying plant. We find in this simulation study, that the economic performance of the two controllers are almost equal. We evaluate the economic performance with an industrially recorded disturbance scenario, where unmeasured disturbances and model mismatch are present. The state of the spray dryer, used in the E-NMPC and MPC, is estimated using Kalman Filters with noise covariances estimated by a maximum likelihood (ML) method.

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Comparison of Prediction Models for a Dual-Hormone Artificial Pancreas

In this paper we compare the performance of five different continuous time transfer function models used in closed-loop model predictive control (MPC). These models describe the glucose-insulin and glucose-glucagon dynamics. They are discretized into a state-space description and used as prediction models in the MPC algorithm. We simulate a scenario including meals and daily variations in the model parameters. The numerical results do not show significant changes in the glucose traces for any of the models, excepted for the first order model. From the present study, we can conclude that the second order model without delay should provide the best trade-off between sensitivity to uncertainties and practical usability for in vivo clinical studies.

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Economic Model Predictive Control for Large-Scale and Distributed Energy Systems

In this thesis, we consider control strategies for large and distributed energy systems that are important for the implementation of smart grid technologies. An electrical grid has to ensure reliability and avoid long-term interruptions in the power supply. Moreover, the share of Renewable Energy Sources (RESs) in the smart grids is increasing. These energy sources bring uncertainty to the production due to their fluctuations. Hence, smart grids need suitable control systems that are able to continuously balance power production and consumption. We apply the Economic Model Predictive Control (EMPC) strategy to optimise the economic performances of the energy systems and to balance the power production and consumption. In the case of large-scale energy systems, the electrical grid connects a high number of power units. Because of this, the related control problem involves a high number of variables and constraints and its solution requires high computational times. Energy systems have a hierarchical control framework and the controllers have to work in the time-scale required by their hierarchy level. Dedicated optimisation techniques efficiently solve the control problem and reduce computational time. We implement the Dantzig-Wolfe decomposition technique to efficiently solve the EMPC problem.

The contributions of this thesis are primarily on:

Large-scale energy system

Smart-grids connect a high number of energy units. In such a large-scale scenario the energy units are independent and dynamically decoupled. The mathematical model of the large-scale energy system embodies the decoupled dynamics of each power units. Moreover, all units of the grid contribute to the overall power production.

Economic Model Predictive Control (EMPC)

This control strategy is an extension of the Model Predictive Control (MPC) strategy. Energy systems often involve stochastic variables due to the share of fluctuating Renewable Energy Sources (RESs). Moreover, the related control problems are multi variables and they are hard, or impossible, to split into single-input-single-output control systems. MPC strategy can handle multi variables control problems and it can embody stochastic variables. The Economic MPC (EMPC) policy optimises the economic performances of the process. In this work, we apply the EMPC to energy systems and it computes the control trajectory for each energy unit. This control policy minimises production costs and ensures that the power production satisfies the customers' demand. The EMPC designs a linear control problem that has a block-angular constraints matrix and it has two sets of constraints. The independent dynamics of the energy units define the decoupling constraints sited on the diagonal. The coupling constraints represent the common goal of all power units in the energy system and this is to satisfy the customers' demand. The Dantzig-Wolfe optimisation technique applies to this structure of the constraints matrix in the view of fastening the control algorithm and increase its applicability.
The Dantzig-Wolfe decomposition solves the EMPC problem through a distributed optimisation technique. The EMPC problem via Dantzig-Wolfe decomposition algorithm computes the optimal input trajectory for each energy unit and reduces the computation times. Moreover, such a control algorithm applies to large-scale energy systems and the number of energy units does not affect the performances of the controller. In this thesis, we also investigate suboptimal solutions of the EMPC problem via modified versions of the Dantzig-Wolfe decomposition algorithms. The feasibility of the suboptimal solutions suffices for stability. The goal of these modified Dantzig-Wolfe decomposition algorithms is to reduce computation time in the solution of the EMPC problem.

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Estimation of Parametric Fault in Closed-loop Systems
The aim of this paper is to present a method for estimation of parametric faults in closed-loop systems. The key technology applied in this paper is coprime factorization of both the dynamic system as well as the feedback controller. Using the Youla-Jabr-Bongiorno-Kucera (YJBK) parameterization, it is shown that a certain matrix transfer function, the fault signature matrix, is an LFT (linear fractional transformation) of the parametric faults. Further, for limit parametric faults, the fault signature matrix transfer function can be approximated with a linear matrix function of the parametric faults.

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Experimental verification of a real-time power curve for down-regulated offshore wind power plants

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Contributors: Giebel, G., Göçmen Bozkurt, T., Sørensen, P. E., Réthoré, P., Poulsen, N. K., Mirzaei, M., Skjelmose, M. R., Kristoffersen, J. R.
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High-Performance Small-Scale Solvers for Moving Horizon Estimation

In this paper we present a moving horizon estimation (MHE) formulation suitable to easily describe the quadratic programs (QPs) arising in constrained and nonlinear MHE. We propose algorithms for factorization and solution of the underlying Karush-Kuhn-Tucker (KKT) system, as well as the efficient implementation techniques focusing on small-scale problems. The proposed MHE solver is implemented using custom linear algebra routines and is compared against implementations using BLAS libraries. Additionally, the MHE solver is interfaced to a code generation tool for nonlinear model predictive control (NMPC) and nonlinear MHE (NMHE). On an example problem with 33 states, 6 inputs and 15 estimation intervals execution times below 500 microseconds are reported for the QP underlying the NMHE.

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Parametric roll resonance monitoring using signal-based detection

Extreme roll motion of ships can be caused by several phenomena, one of which is parametric roll resonance. Several incidents occurred unexpectedly around the millennium and caused vast fiscal losses on large container vessels. The phenomenon is now well understood and some consider parametric roll a curiosity, others have concerns. This study employs novel signal-based detection algorithms to analyse logged motion data from a container vessel (2800 TEU) and a large car and truck carrier (LCTC) during one year at sea. The scope of the study is to assess the performance and robustness of the detection algorithms in real conditions, and to evaluate the frequency of parametric roll events on the selected vessels. Detection performance is scrutinised through the validation of the detected events using owners' standard methods, and supported by available wave radar data. Further, a bivariate statistical analysis of the outcome of the signal-based detectors is performed to assess the real life false alarm probability. It is shown that detection robustness and very low false warning rates are obtained. The study concludes that small parametric roll events are occurring, and that the proposed signal-based monitoring system is a simple and effective mean to provide timely warning of resonance conditions.

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Real-time available power estimation for offshore wind power plants

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Contributors: Göçmen Bozkurt, T., Giebel, G., Sørensen, P. E., Réthoré, P., Mirzaei, M., Poulsen, N. K., Skjelmose, M. R., Kristoffersen, J. R.
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The contribution of glucagon in an Artificial Pancreas for people with type 1 diabetes

The risk of hypoglycemia is one of the main concerns in treatment of type 1 diabetes (T1D). In this paper we present a head-to-head comparison of a currently used insulin-only controller and a prospective bihormonal controller for blood glucose in people with T1D. The bihormonal strategy uses insulin to treat hyperglycemia as well as glucagon to ensure fast recovery from hypoglycemic episodes. Two separate model predictive controllers (MPC) based on patient-specific models handle insulin and glucagon infusion. In addition, the control algorithm consists of a Kalman filter and a meal time insulin bolus calculator. The feedback is obtained from a continuous glucose monitor (CGM). We implement a bihormonal simulation model with time-varying parameters available for 3 subjects to compare the strategies. We consider a protocol with 3 events - a correct mealtime insulin bolus, a missed bolus and a bolus overestimated by 60%. During normal operation both strategies provide similar results. The contribution of glucagon becomes evident after administration of the overestimated insulin bolus. In a 10h period following an overbolused meal, the bihormonal strategy reduces time spent in hypoglycemia in the most severe case by almost 15% (1.5h), outperforming the insulin-only control. Therefore, glucagon contributes to the safety of an Artificial Pancreas.

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Turbine Control Strategies for Wind Farm Power Optimization

In recent decades there has been increasing interest in green energies, of which wind energy is the most important one. In order to improve the competitiveness of the wind power plants, there are ongoing researches to decrease cost per energy unit and increase the efficiency of wind turbines and wind farms. One way of achieving these goals is to optimize the power generated by a wind farm. One optimization method is to choose appropriate operating points for the individual wind turbines in the farm. We have made three models of a wind farm based on three difference control strategies.
Basically, the control strategies determine the steady state operating points of the wind turbines. Except the control strategies of the individual wind turbines, the wind farm models are similar. Each model consists of a row of 5MW reference wind turbines. In the models we are able to optimize the generated power by changing the power reference of the individual wind turbines. We use the optimization setup to compare power production of the wind farm models. This paper shows that for the most frequent wind velocities (below and around the rated values), the generated powers of the wind farms are different. This means that choosing an appropriate control strategy for the individual wind turbines will result in an increased power production of the wind farm.

**Active fault detection in MIMO systems**

The focus in this paper is on active fault detection (AFD) for MIMO systems with parametric faults. The problem of design of auxiliary inputs with respect to detection of parametric faults is investigated. An analysis of the design of auxiliary inputs is given based on analytic transfer functions from auxiliary input to residual outputs. The analysis is based on a singular value decomposition of these transfer functions. Based on this analysis, it is possible to design auxiliary input as well as design of the associated residual vector with respect to every single parametric fault in the system such that it is possible to detect these faults.

**Active Fault Isolation in MIMO Systems**

Active fault isolation of parametric faults in closed-loop MIMO systems are considered in this paper. The fault isolation consists of two steps. The first step is group-wise fault isolation. Here, a group of faults is isolated from other possible faults in the system. The group-wise fault isolation is based directly on the input/output signals applied for the fault detection. It is guaranteed that the fault group includes the fault that had occurred in the system. The second step is individual fault isolation in the fault group. Both types of isolation are obtained by applying dedicated auxiliary inputs and the associated residual outputs.
Active load reduction by means of trailing edge flaps on a wind turbine blade

This paper presents the blade fatigue load reduction achieved with a trailing edge flap during a full scale test on a Vestas V27 wind turbine. A frequency-weighted linear model predictive control (MPC) is tuned to decrease flapwise blade root fatigue loads at the frequencies where most of the blade damage occurs, i.e. the 1P and 2P frequencies (respectively 1 and 2 events per revolution). Frequency-weighted MPC is chosen for its ability to handle constraints on the trailing edge flap deflection and to optimise its actuation in order to decrease wear and tear of the actuator. The controller was first tested in aero-servo-elastic simulations, before being implemented on a Vestas V27 wind turbine. Consistent load reduction is achieved during the full-scale test. An average of 14% flapwise blade root fatigue load reduction is measured.

A Dantzig-Wolfe decomposition algorithm for linear economic model predictive control of dynamically decoupled subsystems

This paper presents a warm-started Dantzig–Wolfe decomposition algorithm tailored to economic model predictive control of dynamically decoupled subsystems. We formulate the constrained optimal control problem solved at each sampling instant as a linear program with state space constraints, input limits, input rate limits, and soft output limits. The objective function of the linear program is related directly to the cost of operating the subsystems, and the cost of violating the soft output constraints. Simulations for large-scale economic power dispatch problems show that the proposed algorithm is significantly faster than both state-of-the-art linear programming solvers, and a structure exploiting implementation of the alternating direction method of multipliers. It is also demonstrated that the control strategy presented in this paper can be tuned using a weighted ℓ₁-regularization term. In the presence of process and measurement noise, such a regularization term is critical for achieving a well-behaved closed-loop performance.

Adaptive Passivity Based Individual Pitch Control for Wind Turbines in the Full Load Region
This paper tackles the problem of power regulation for wind turbines operating in the top region by an adaptive passivity based individual pitch control strategy. An adaptive nonlinear controller that ensures passivity of the mapping aerodynamic torque-regulation error is proposed, where the inclusion of gradient based adaptation laws allows for the on-line compensation of variations in the aerodynamic torque. The closed-loop equilibrium point of the regulation error dynamics is shown to be UGAS (uniformly globally asymptotically stable). Numerical simulations show that the proposed control strategy succeeds in regulating the power output of the wind turbine despite fluctuations of the wind field due to wake and turbulence, without overloading the pitch actuators.

Application of Constrained Linear MPC to a Spray Dryer
In this paper we develop a linear model predictive control (MPC) algorithm for control of a two stage spray dryer. The states are estimated by a stationary Kalman filter. A non-linear first-principle engineering model is developed to simulate the spray drying process. The model is validated against experimental data and able to precisely predict the temperatures, the air humidity and the residual moisture in the dryer. The MPC controls these variables to the target and reject disturbances. Spray drying is a cost-effective method to evaporate water from liquid foods and produces a free flowing powder. The main challenge of spray drying is to meet the residual moisture specification and prevent powder from sticking to the chamber walls. By simulation we compare the performance of the MPC against the conventional PID control strategy. During an industrially recorded disturbance scenario, the MPC increases the production rate by 7.9%, profit of production by 8.2% and the energy efficiency by 4.1% on average.
A Reduced Dantzig-Wolfe Decomposition for a Suboptimal Linear MPC

Linear Model Predictive Control (MPC) is an efficient control technique that repeatedly solves online constrained linear programs. In this work we propose an economic linear MPC strategy for operation of energy systems consisting of multiple and independent power units. These systems cooperate to meet the supply of power demand by minimizing production costs. The control problem can be formulated as a linear program with block-angular structure. To speed-up the solution of the optimization control problem, we propose a reduced Dantzig-Wolfe decomposition. This decomposition algorithm computes a suboptimal solution to the economic linear MPC control problem and guarantees feasibility and stability. Finally, six scenarios are performed to show the decrease in computation time in comparison with the classic Dantzig-Wolfe algorithm.

Assessment of Model Predictive and Adaptive Glucose Control Strategies for People with Type 1 Diabetes

This paper addresses overnight blood glucose stabilization in people with type 1 diabetes using a Model Predictive Controller (MPC). We use a control strategy based on an adaptive ARMAX model in which we use a Recursive Extended Least Squares (RELS) method to estimate parameters of the stochastic part. We compare this model structure with an autoregressive integrated moving average with exogenous input (ARIMAX) structure, and with an autoregressive moving average with exogenous input (ARMAX) model, i.e. without an integrator. Additionally, safety layers improve the controller robustness and reduce the risk of hypoglycemia. We test our control strategies on a virtual clinic of 100 randomly generated patients with a representative inter-subject variability. This virtual clinic is based on the Hovorka model. We consider the case where only half of the meal bolus is administered at mealtime, and the case where the insulin sensitivity varies during the night. The simulation results demonstrate that the adaptive control strategy can reduce the risks of hypoglycemia and hyperglycemia during the night.
Bihormonal model predictive control of blood glucose in people with type 1 diabetes
In this paper we present a bihormonal control system that controls blood glucose in people with type 1 diabetes (T1D). We use insulin together with glucagon to mitigate the negative effects of hyper- and hypoglycemia. The system consists of a Kalman filter, a micro-bolus insulin and glucagon infusion MPC, a mealtime bolus calculator and a CGM providing feedback to the controller. The controller employs a patient data-based prediction model with ARMAX structure. We test the controller using a bihormonal model with time-varying parameters for 3 subjects and compare its performance to a system with an identical insulin MPC, but a glucagon PD controller. The key contribution of the bihormonal MPC is the efficiency of glucagon use. We consider scenarios where the meals are estimated correctly or overestimated and where the insulin sensitivity increases. Both solutions provide tight glucose control. According to the simulations, the bihormonal MPC requires on average 30% less glucagon than the system with a PD controller.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Center for Energy Resources Engineering, Scientific Computing, Slovak University of Technology, Danish Diabates Academy, Copenhagen University Hospital
Contributors: Batora, V., Tarnik, M., Murgas, J., Schmidt, S., Nørgaard, K., Poulsen, N. K., Madsen, H., Jørgensen, J. B.
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Controller modification applied for active fault detection
This paper is focusing on active fault detection (AFD) for parametric faults in closed-loop systems. This auxiliary input applied for the fault detection will also disturb the external output and consequently reduce the performance of the controller. Therefore, only small auxiliary inputs are used with the result that the detection and isolation time can be long. In this paper it will be shown, that this problem can be handled by using a modification of the feedback controller. By applying the YJBK-parameterization (after Youla, Jabr, Bongiorno and Kucera) for the controller, it is possible to modify the feedback controller with a minor effect on the external output in the fault free case. Further, in the faulty case, the signature of the auxiliary input can be optimized. This is obtained by using a band-pass filter for the YJBK parameter that is only effective in a small frequency range where the frequency for the auxiliary input is selected. This gives that it is possible to apply an auxiliary input with a reduced amplitude. An example is included to show the results.

General information
State: Published
Organisations: Department of Electrical Engineering, Automation and Control, Department of Applied Mathematics and Computer Science, Dynamical Systems, Aalborg University
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10.1109/ACC.2014.6858784
Economic Optimization of Spray Dryer Operation using Nonlinear Model Predictive Control
In this paper we investigate an economically optimizing Nonlinear Model Predictive Control (E-NMPC) for a spray drying process. By simulation we evaluate the economic potential of this E-NMPC compared to a conventional PID based control strategy: Spray drying is the preferred process to reduce the water content for many liquid foodstuffs and produces a free flowing powder. The main challenge in controlling the spray drying process is to meet the residual moisture specifications and avoid that the powder sticks to the chamber walls of the spray dryer. We present a model for a spray dryer that has been validated on experimental data from a pilot plant. We use this model for simulation as well as for prediction in the E-NMPC. The E-NMPC is designed with hard input constraints and soft output constraints. The open-loop optimal control problem in the E-NMPC is solved using the single-shooting method combined with a quasi-Newton Sequential Quadratic Programming (SQP) algorithm and the adjoint method for computation of gradients. The E-NMPC improves the cost of spray drying by 26.7% compared to conventional PI control in our simulations.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Department of Electrical Engineering, Automation and Control, Center for Energy Resources Engineering, GEA Process Engineering A/S
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Estimation of the Possible Power of a Wind Farm
It seems possible to increase competitiveness of wind power plants by offering grid services (also called ancillary services) and enter the wind power plants into the ancillary market. One of the ancillary services is called reserve power, the differential capacity between the generated power and the available power in the farm. The total amount of energy that a wind farm can potentially generate is called possible power. It is very important for a wind farm owner to have a relatively accurate estimate of the possible power of the wind farm in order to be able to trade the reserve power. In this paper the possible power calculated based on the estimated effective wind speed of a down regulated wind farm (the industry standard) is compared against the calculated possible power based on the algorithm presented in the paper. The latter takes into account the eect of the wakes of down regulated turbines and therefore gives a more accurate measure of the possible power. It is shown that for an interval of wind speeds the difference between these two can increase the uncertainty in the estimate of the possible power of the down regulated wind farm.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Department of Wind Energy, Wind Energy Systems, Dynamical Systems
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Full-scale test of trailing edge flaps on a Vestas V27 wind turbine: active load reduction and system identification

A full-scale test was performed on a Vestas V27 wind turbine equipped with one active 70 cm long trailing edge flap on one of its 13 m long blades. Active load reduction could be observed in spite of the limited spanwise coverage of the single active trailing edge flap. A frequency-weighted model predictive control was tested successfully on this demonstrator turbine. An average flapwise blade root load reduction of 14% was achieved during a 38 minute test, and a reduction of 20% of the amplitude of the 1P loads was measured. A system identification test was also performed, and an identified linear model, from trailing edge flap angle to flapwise blade root moment, was derived and compared with the linear analytical model used in the model predictive control design model. Flex5 simulations run with the same model predictive control showed a good correlation between the simulations and the measurements in terms of flapwise blade root moment spectral densities, in spite of significant differences between the identified linear model and the model predictive control design model.
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<td>CiteScore 2.36, SJR 1.062, SNIP 2.297</td>
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<td>2002</td>
<td>BFI-level 2</td>
<td>CiteScore 2.36, SJR 1.062, SNIP 2.297</td>
<td>Indexed yes</td>
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IMU Calibration and Validation in a Factory, Remote on Land and at Sea
This paper treats the IMU calibration and validation problem in three settings: Factory production line with the aid of a precision multi-axis turntable, in-the-field on land and at sea, both without specialist test equipment. The treatment is limited to the IMU calibration parameters of key relevance for gyro-compassing grade optical gyroscopes and force-rebalanced pendulous accelerometers: Scale factor, bias and sensor axes misalignments. Focus is on low-dynamic marine applications e.g., subsea construction and survey. Two different methods of calibration are investigated: Kalman smoothing using an Aided Inertial Navigation System (AINS) framework, augmenting the error state Kalman filter (ESKF) to include the full set of IMU calibration parameters and a least squares approach, where the calibration parameters are determined by minimizing the magnitude of the INS error differential equation output. A method of evaluating calibrations is introduced and discussed. The two calibration methods are evaluated for factory use and results compared to a legacy proprietary method as well as in-field calibration/verification on land and at sea. The calibration methods shows similar navigation performance as the proprietary method. This validates both methods for factory calibration. Furthermore it is shown that the AINS method can calibrate in-field on land and at sea without the use of a precision multi-axis turntable.

Model based active power control of a wind turbine
In recent decades there has been increasing interest in green energies, of which wind energy is one of the most important. Wind turbines are the most common wind energy conversion systems and are hoped to be able to compete with traditional power plants in near future. This demands better technology to increase competitiveness of the wind power plants. One way to increase competitiveness of wind power plants is to offer grid services (also called ancillary services) that are normally offered by traditional power plants. One of the ancillary services is called reserve power. There are instants in the electricity market that selling the reserve power is more profitable than producing with the full capacity. Therefore wind turbines can be down-regulated and sell the differential capacity as the reserve power. In this paper we suggest a model based approach to control wind turbines for active power reference tracking. We use model predictive control (MPC) as our control method. We compare three different control strategies, namely Max-Ω, Constant-Ω and Constant-λ and discuss their drawbacks and benefits by presenting analysis of the steady state operating points and simulations on a high fidelity wind turbine model.
Model Predictive Control for Smart Energy Systems

In this thesis, we consider control strategies for flexible distributed energy resources in the future intelligent energy system – the Smart Grid. The energy system is a large-scale complex network with many actors and objectives in different hierarchical layers. Specifically the power system must supply electricity reliably to both residential and industrial consumers around the clock. More and more fluctuating renewable energy sources, like wind and solar, are integrated in the power system. Consequently, uncertainty in production starts to affect an otherwise controllable power production significantly. A Smart Grid calls for flexible consumers that can adjust their consumption based on the amount of green energy in the grid. This requires coordination through new large-scale control and optimization algorithms. Trading of flexibility is key to drive power consumption in a sustainable direction. In Denmark, we expect that distributed energy resources such as heat pumps, and batteries in electric vehicles will mobilize part of the needed flexibility.

Our primary objectives in the thesis were threefold:

1. Simulate the components in the power system based on simple models from literature (e.g. heat pumps, heat tanks, electrical vehicle battery charging/discharging, wind farms, power plants).
2. Embed forecasting methodologies for the weather (e.g. temperature, solar radiation), the electricity consumption, and the electricity price in a predictive control system.
3. Develop optimization algorithms for large-scale dynamic systems. This includes decentralized optimization and simulation on realistic large-scale dynamic systems.

Chapter 1 introduces the power system, the markets, and the main actors. The objectives and control hierarchy is outlined while Aggregators are introduced as new actors.

Chapter 2 provides linear dynamical models of Smart Grid units: Electric Vehicles, buildings with heat pumps, refrigeration systems, solar collectors, heat storage tanks, power plants, and wind farms. The models can be realized as discrete time state space models that fit into a predictive control system.

Chapter 3 introduces Model Predictive Control (MPC) including state estimation, filtering and prediction for linear models.

Chapter 4 simulates the models from Chapter 2 with the certainty equivalent MPC from Chapter 3. An economic MPC minimizes the costs of consumption based on real electricity prices that determined the flexibility of the units. A predictive control system easily handles constraints, e.g. limitations in power consumption, and predicts the future behavior of a unit by integrating predictions of electricity prices, consumption, and weather variables. The simulations demonstrate the expected load shifting capabilities of the units that adapts to the given price predictions. We furthermore evaluated control performance in terms of economic savings for different control strategies and forecasts.

Chapter 5 describes and compares the proposed large-scale Aggregator control strategies. Aggregators are assumed to play an important role in the future Smart Grid and coordinate a large portfolio of units. The developed economic MPC controllers interfaces each unit directly to an Aggregator. We developed several MPC-based aggregation strategies that coordinates the global behavior of a portfolio of units by solving a large-scale optimization and control problem. We applied decomposition methods based on convex optimization, such as dual decomposition and operator splitting, and developed price-based aggregator strategies.

Chapter 6 provides conclusions, contributions and future work.
The main scientific contributions can be summarized to:

- Linear dynamical models of flexible Smart Grid units: heat pumps in buildings, heat storage tanks, and electric vehicle batteries.
- Economic MPC that integrates forecasts in the control of these flexible units.
- Large-scale distributed control strategies based on economic MPC, convex optimization, and decomposition methods.
- A Matlab toolbox including the modeled units for simulating a Smart Energy System with MPC.

Wind Speed Estimation and Parameterization of Wake Models for Downregulated Offshore Wind Farms

The estimation of possible (or available) power of a downregulated offshore wind farm is the content of the PossPOW project (See PossPOW Poster ID: 149). The main challenges of this estimation process are:

1) to determine the free stream equivalent wind speed at the turbine level since the accuracy of nacelle anemometers are in question and power curve derivation is no longer applicable during downregulation

2) to apply a real-time wake model which can calculate the power production as if the wind farm was operating normally even in short downregulation periods. However, most existing wake models have only been used to acquire long term, statistical information and verified using 10-min averaged data

The proposed methodologies to overcome those challenges are presented in this poster.

Wind Speed Estimation and Parametrization of Wake Models for Downregulated Offshore Wind Farms within the scope of PossPOW Project

With increasing installed capacity, wind farms are requested to downregulate more frequently, especially in the offshore environment. Determination and verification of possible (or available) power of downregulated offshore wind farms are the aims of the PossPOW project (see PossPOW.dtu.dk). Two main challenges encountered in the project so far are the estimation of wind speed and the recreation of the flow inside the downregulated wind farm as if it is operating ideally. The rotor effective wind speed was estimated using power, pitch angle and rotational speed as inputs combined with a generic Cp model. The results have been compared with Horns Rev-I dataset and NREL 5MW simulations under both downregulation and normal operation states. For the real-time flow recreation, the GCLarsen single wake model was re-calibrated using a 1-s dataset from Horns Rev and tested for the downregulated period. The re-calibrated model has to be further parametrized to include dynamic effects such as wind direction variability and meandering also considering different averaging time scales before implemented in full scale wind farms.
A Grey-Box Model for Spray Drying Plants

Multi-stage spray drying is an important and widely used unit operation in the production of food powders. In this paper we develop and present a dynamic model of the complete drying process in a multi-stage spray dryer. The dryer is divided into three stages: The spray stage and two fluid bed stages. Each stage is assumed ideally mixed and described by mass- and energy balances. The model is able to predict the temperature, the residual moisture and the particle size in each stage. Process constraints are also proposed to predict deposits due to stickiness of the powder. The model predictions are compared to datasets gathered at GEA Process Engineering’s test facility. The identified grey-box model parameters are identified from data and the resulting model fits the data well. The complexity of the model has been selected such that it is suitable for development of real-time optimization algorithms in an economic optimizing MPC framework.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Department of Electrical Engineering, Automation and Control, Center for Energy Resources Engineering, GEA Process Engineering A/S
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An MPC approach to individual pitch control of wind turbines using uncertain LIDAR measurements

Spatial distribution of the wind field exerts unbalanced loads on wind turbine structures and it is shown these loads could be mitigated by controlling each blade’s angle individually (individual pitch control). In this work the problem of individual pitch control of a variable-speed variable-pitch wind turbine in the full load region is considered. Model predictive control (MPC) is used to solve the problem. A new approach is proposed to simplify the optimization problem of MPC. We linearize the obtained nonlinear model for different operating points which are determined by the effective wind speed on the rotor disc and take the wind speed as a scheduling variable. The wind speed is measurable ahead of the turbine using LIDARs, therefore the scheduling variable is known for the entire prediction horizon. We consider uncertainty in the wind propagation, which is the traveling time of wind from the LIDAR measurement point to the rotor. An algorithm based on wind speed estimation and measurements from the LIDAR is devised to find an estimate of the delay and compensate for it before it is used in the controller. Comparisons between the MPC with error compensation, without error compensation and a benchmark cyclic pitch PI controller are given. The results show that with appropriate signal processing techniques, LIDAR measurements improve the performance of the wind turbine controller.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Electrical Engineering, Automation and Control, Aalborg University
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A simplified dynamic inflow model and its effect on the performance of free mean wind speed estimation

Model-based state space controllers require knowledge of states, both measurable and unmeasurable, and state estimation algorithms are typically employed to obtain estimates of the unmeasurable states. For the control of wind turbines, a good estimate of the free mean wind speed is important for the closed-loop dynamics of the system, and an appropriate level of modelling detail is required to obtain good estimates of the free mean wind speed. In this work, three aerodynamic models based on blade element momentum theory are presented and compared with the aero-servo-elastic code HAWC2. The first model, known as quasi-steady aerodynamics, assumes instant equilibrium of the wind turbine wake, a modelling approach often used by model-based control algorithms. The second model includes the dynamic wake also known as dynamic inflow and gives a more correct description of the actual physics of the wind turbine wake. The dynamic inflow model includes a number of dynamic states proportional to the number of radial points in the spatially discretised blade formulation. The large number of dynamic states inhibits the use of this model in model-based control and estimation algorithms. The lack of dynamic inflow in the first model and large number of dynamic states in the second model lead to a third model, a simplified dynamic inflow model, which with only a single dynamic state is still able to capture the most significant dynamics of the more advanced dynamic inflow model. Simulations in the aero-servo-elastic code HAWC2 compare the ability to estimate the free mean wind speed when either the first or third model is included in the estimation algorithm. Both a simplified example with a deterministic step in wind speed and full degrees-of-freedom simulations with turbulent wind fields clearly show that the inclusion of the dynamic inflow model in the free wind speed estimation algorithm is important for good free mean wind speed estimates.

General information

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Contributors: Henriksen, L. C., Hansen, M. H., Poulsen, N. K.
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BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 3.18 SJR 1.051 SNIP 1.834
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Web of Science (2017): Indexed yes
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Web of Science (2016): Impact factor 2.725
Web of Science (2016): Indexed yes
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Scopus rating (2015): CiteScore 3.06 SJR 1.201 SNIP 2.165
Web of Science (2015): Impact factor 2.891
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Scopus rating (2014): CiteScore 3.42 SJR 1.209 SNIP 3.688
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Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 2.75 SJR 1.235 SNIP 2.486
Computational Efficiency of Economic MPC for Power Systems Operation

In this work, we propose an Economic Model Predictive Control (MPC) strategy to operate power systems that consist of independent power units. The controller balances the power supply and demand, minimizing production costs. The control problem is formulated as a linear program that is solved by a computationally efficient implementation of the Dantzig-Wolfe decomposition. To make the controller suitable for realtime applications, we investigate a suboptimal MPC scheme, introducing an early termination strategy to the Dantzig-Wolfe algorithm. Simulations demonstrate that the early termination technique substantially reduces the computation time.

General information

State: Published
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Contributors: Standardi, L., Poulsen, N. K., Jørgensen, J. B., Sokoler, L. E.
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Publication date: 2013
Decentralized Large-Scale Power Balancing

A power balancing strategy based on Douglas-Rachford splitting is proposed as a control method for large-scale integration of flexible consumers in a Smart Grid. The total power consumption is controlled through a negotiation procedure between all units and a coordinating system level. The balancing problem is formulated as a centralized large-scale optimization problem but is then decomposed into smaller subproblems that are solved locally by each unit connected to an aggregator. For large-scale systems the method is faster than solving the full problem and can be distributed to include an arbitrary number of units.

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Contributors: Halvgaard, R., Jørgensen, J. B., Poulsen, N. K., Madsen, H., Vandenberghe, L.
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Early Detection of Parametric Roll Resonance on Container Ships

Parametric roll resonance on ships is a nonlinear phenomenon where waves encountered at twice the natural roll frequency can bring the vessel dynamics into a bifurcation mode and lead to extreme values of roll. Recent years have seen several incidents with dramatic damage to container vessels. The roll oscillation, which is subharmonic with respect to the wave excitation, may be completely unexpected and a system for detection of the onset of such resonance could warn the navigators before roll angles reach serious levels. Timely warning could make remedial actions possible, such as change the ship’s speed and course, to escape from the bifurcation condition. This paper proposes nonparametric methods to detect the onset of roll resonance and demonstrates their performance. Theoretical conditions for parametric resonance are revisited and are used to develop efficient methods to detect its onset. Spectral and temporal correlations of the square of roll with pitch (or heave) are demonstrated to be of particular interest as indicators. Properties of the indicators are scrutinized, and a change detector is designed for the Weibull-type of distributions that were observed from a time-domain indicator for phase correlation. Hypothesis testing for resonance is developed using a combination of detectors to obtain robustness. Conditions of forced roll and disturbances in real weather conditions are analyzed and robust detection techniques are suggested. The efficacy of the methodology is shown on experimental data from model tests and on data from a container ship crossing the Atlantic during a storm.

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Early Termination of Dantzig-Wolfe Algorithm for Economic MPC
In this paper we apply the Economic Model Predictive Control (MPC) for balancing the power supply and demand in the future power systems in the most economic way. The control problem is formulated as a linear program, having a block-angular structure solved by the implementation of the Dantzig-Wolfe decomposition. For real-time applications we introduce an early termination technique. Simulations demonstrate that the algorithm developed operates efficiently a power system, reducing significantly computational time.

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Source: dtu
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Frequency-Weighted Model Predictive Control of Trailing Edge Flaps on a Wind Turbine Blade
This paper presents the load reduction achieved with trailing edge flaps during a full-scale test on a Vestas V27 wind turbine. The trailing edge flap controller is a frequency-weighted linear model predictive control (MPC) where the quadratic cost consists of costs on the zero-phase filtered flapwise blade root moment and trailing edge flap deflection. Frequency-weighted MPC is chosen for its ability to handle constraints on the trailing edge flaps deflection, and to target at loads with given frequencies only. The controller is first tested in servo-aeroelastic simulations, before being implemented on a Vestas V27 wind turbine. Consistent load reduction is achieved during the full-scale test. An average of 13.8% flapwise blade root fatigue load reduction is measured.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Wind Energy, Wind Turbines, Vestas Wind Systems AS
Contributors: Castaignet, D., Couchman, I., Poulsen, N. K., Buhl, T., Wedel-Heinen, J. J.
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Volume: 21
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Frequency weighted model predictive control of wind turbine
This work is focused on applying frequency weighted model predictive control (FMPC) on three blade horizontal axis wind turbine (HAWT). A wind turbine is a very complex, non-linear system influenced by a stochastic wind speed variation. The reduced dynamics considered in this work are the rotational degree of freedom of the rotor and the tower for-aft movement. The MPC design is based on a receding horizon policy and a linearised model of the wind turbine. Due to the change of dynamics according to wind speed, several linearisation points must be considered and the control design adjusted accordingly. In practice it is very hard to measure the effective wind speed, this quantity will be estimated using measurements from the turbine itself. For this purpose stationary predictive Kalman filter has been used. Stochastic simulations of the wind turbine behaviour with applied frequency weighted model predictive controller are presented. Statistical comparison between frequency weighted MPC, standard MPC and baseline PI controller is shown as well.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Electrical Engineering, Automation and Control, Slovak University of Technology
Contributors: Klauco, M., Poulsen, N. K., Mirzaei, M., Niemann, H. H.
Pages: 347-352
Publication date: 2013

Model-Based Closed-Loop Glucose Control in Type 1 Diabetes: The DiaCon Experience
Background:
To improve type 1 diabetes mellitus (T1DM) management, we developed a model predictive control (MPC) algorithm for closed-loop (CL) glucose control based on a linear second-order deterministic-stochastic model. The deterministic part of the model is specified by three patient-specific parameters: insulin sensitivity factor, insulin action time, and basal insulin infusion rate. The stochastic part is identical for all patients but identified from data from a single patient. Results of the first clinical feasibility test of the algorithm are presented.

Methods:
We conducted two randomized crossover studies. Study 1 compared CL with open-loop (OL) control. Study 2 compared glucose control after CL initiation in the euglycemic (CL-Eu) and hyperglycemic (CL-Hyper) ranges, respectively. Patients were studied from 22:00–07:00 on two separate nights.

Results:
Each study included six T1DM patients (hemoglobin A1c 7.2% ± 0.4%). In study 1, hypoglycemic events (plasma glucose < 54 mg/dl) occurred on two OL and one CL nights. Average glucose from 22:00–07:00 was 90 mg/dl [74–146 mg/dl; median (interquartile range)] during OL and 108 mg/dl (101–128 mg/dl) during CL (determined by continuous glucose monitoring). However, median time spent in the range 70–144 mg/dl was 67.9% (3.0–73.3%) during OL and 80.8% (70.5–89.7%) during CL. In study 2, there was one episode of hypoglycemia with plasma glucose <54 mg/dl in a CL-Eu night. Mean glucose from 22:00–07:00 and time spent in the range 70–144 mg/dl were 121 mg/dl (117–133 mg/dl) and 69.0% (30.7–77.9%) in CL-Eu and 149 mg/dl (140–193 mg/dl) and 48.2% (34.9–72.5%) in CL-Hyper, respectively.

Conclusions:
This study suggests that our novel MPC algorithm can safely and effectively control glucose overnight, also when CL control is initiated during hyperglycemia.

General information
State: Published
Model Predictive Control of Wind Turbines using Uncertain LIDAR Measurements

The problem of Model predictive control (MPC) of wind turbines using uncertain LIDAR (LIght Detection And Ranging) measurements is considered. A nonlinear dynamical model of the wind turbine is obtained. We linearize the obtained nonlinear model for different operating points, which are determined by the effective wind speed on the rotor disc. We take the wind speed as a scheduling variable. The wind speed is measurable ahead of the turbine using LIDARs, therefore, the scheduling variable is known for the entire prediction horizon. By taking the advantage of having future values of the scheduling variable, we simplify state prediction for the MPC. Consequently, the control problem of the nonlinear system is simplified into a quadratic programming. We consider uncertainty in the wind propagation time, which is the traveling time of wind from the LIDAR measurement point to the rotor. An algorithm based on wind speed estimation and measurements from the LIDAR is devised to find an estimate of the delay and compensate for it before it is used in the controller.
Comparisons between the MPC with error compensation, the MPC without error compensation and an MPC with re-linearization at each sample point based on wind speed estimation are given. It is shown that with appropriate signal processing techniques, LIDAR measurements improve the performance of the wind turbine controller.

PossPOW: possible Power of Downregulated Offshore Wind Power Plants

Introduction
In recent years, the very large offshore wind farms were designed as wind power plants, including possibilities to contribute to the stability of the grid by offering grid services (also called ancillary services). One of those services is reserve power, which is achieved by down-regulating the wind farm from its maximum possible power. The power can be ramped up quite quickly, but the influence of wakes makes it difficult to assess the exact amount of down-regulation available to sell. Currently, Transmission System Operators (TSOs) have no real way to determine exactly the possible power of a down-regulated wind farm.

Approach
The technology we want to develop draws together models from various disciplines, including wake modelling of large offshore wind farms, aerodynamic models for wind turbines, stochastic model estimation and computer simulations. During the project, the findings will be verified on some of the large offshore wind farms owned by Vattenfall, and possibly in a DONG Energy wind farm too. Dedicated experiments to the wind flow in large offshore wind farms are planned.

Main body of abstract
Modern wind turbines have a SCADA signal called possible power. In normal operation, this would be the actual power, but during down-regulation it would give the possible power given the current wind regime. In a down-regulated wind farm, the sum of the possible and actual power during down-regulation is not the same as the regulation power reserve in that wind farm, since turbines downwind of down-regulated turbines see more wind that would be there without the regulation. Wake modelling is necessary in order to take into account that the wakes will change when the wind farm is down regulated. The PossPOW project will not develop new wake models, but adjust the Dynamic Wake Meandering model and/or Fuga for real-time use.

The proposed technique is to use the same wake model for two steps to calculate possible power in a down regulated case:
1. First, the ambient flow will be derived in the actual down regulated case, using wind turbines thrusts from the down regulated wind turbines. This is an inverse way of using wake models, using the wake flow as input and the ambient flow as output.
2. Secondly, the wake flow in the possible power case will be derived from the ambient flow derived in 1, using wind
turbines thrusts in the possible power case. This is the normal way of using wake models, using the ambient flow as input and wake flow as output.

Conclusion

The poster presents a new Danish project on the possible power from a down-regulated wind farm. Project partners are DTU, Vestas, Siemens, Vattenfall and DONG. We aim at a verified and internationally accepted way to determine the possible power of a down-regulated offshore wind farm, taking into account the meteorology and wake effects. Along the way, we also aim at improving the use of wake models for real-time cases. Please see posspow.dtu.dk.

General information

State: Published
Contributors: Giebel, G., Göçmen, T., Sørensen, P. E., Poulsen, N. K., Runge Kristoffersen, J.
Number of pages: 5
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Electronic versions: PossPOW.pdf
Research output: Research - peer-review › Article in proceedings – Annual report year: 2013

The Potential of Economic Model Predictive Control for Spray Drying Plants

In 2015 the milk quota system in the European Union will be completely liberalized. As a result, analysts expect production of skimmed and whole milk powder to increase by 5-6% while its price will decline by about 6-7%. Multi-stage spray drying is the prime process for the production of food powders. The process is highly energy consuming and capacity depends among other factors on correct control of the dryer. Consequently efficient control and optimization of the spray drying process has become increasingly important to accommodate the future market challenges.

The goal of the presentation is to present our results regarding modeling of the process and how the efficiency and profitability can be lifted by introducing an economic optimizing MPC scheme.

Firstly, we develop a first-principle engineering model that can be used to simulate spray drying processes with high accuracy. The model can be adjusted to describe drying of various products and describes the complete drying process of a multi-stage spray dryer. The dryer is divided into three stages, the spray stage and two uid bed stages. Each stage is assumed ideally mixed and described by mass- and energy balances. The model is able to predict outlet temperatures, the residual moisture and particle size of the product. We also give a novel approach to predict deposits due to stickiness of the powder. The model predictions are compared to datasets gathered at GEA Process Engineering's test facility. The identified model parameters are identified from data and the resulting model fits the data well.

Secondly, the effect of disturbances, ambient air humidity and solids content in the feed, is studied by simulation. We show that conventional control is insufficient at controlling the product quality as well as driving the plant to the most economic conditions. Furthermore, we show that the efficiency can be increased by correct adjustment of heat and inlet air ow at each stage.

The recent focus in research has shifted from reference tracking MPC to optimization of economic objective functions. We will discuss how this optimization can be performed by advanced process control techniques, such as Economic Model Predictive Control (E-MPC). We suggest adding an E-MPC based supervisory control layer on top of the contemporary PI-controllers. The strong interconnection between drying stages and process constraints are well suited for MPC.

General information

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Department of Electrical Engineering, Automation and Control, Center for Energy Resources Engineering, GEA Process Engineering A/S
Contributors: Petersen, L. N., Poulsen, N. K., Niemann, H. H., Utzen, C., Jørgensen, J. B.
Number of pages: 1
Publication date: 2013
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Event: Abstract from 18th Nordic Process Control Workshop, Oulu, Finland.
Keywords: Spray drying, Multi-Stage dryer, Grey-box model, First-principles model
Electronic versions:
Thermal Storage Power Balancing with Model Predictive Control

The method described in this paper balances power production and consumption with a large number of thermal loads. Linear controllers are used for the loads to track a temperature set point, while Model Predictive Control (MPC) and model estimation of the load behavior are used for coordination. The total power consumption of all loads is controlled indirectly through a real-time price. The MPC incorporates forecasts of the power production and disturbances that influence the loads, e.g. time-varying weather forecasts, in order to react ahead of time. A simulation scenario demonstrates that the method allows for the integration of flexible thermal loads in a smart energy system in which consumption follows the changing production.

General information
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Organisations: Center for Energy Resources Engineering, Department of Applied Mathematics and Computer Science , Dynamical Systems
Contributors: Halvgaard, R., Poulsen, N. K., Madsen, H., Jørgensen, J. B.
Pages: 2567-2572
Publication date: 2013

A Dantzig-Wolfe Decomposition Algorithm for Linear Economic MPC of a Power Plant Portfolio

Recently, the interest in renewable energy sources is increasing. In the short future, their penetration in the power systems will be significantly higher than today. Denmark is working on achieving its goal by 2020 of having 30% of the energy production provided by renewable sources, 50% of the total power consumption is expected to stem from wind turbines. Due to the inherent stochasticity in renewable energy systems (RES), their energy production is usually complicated to forecast and control. The aim of the smart grid in which consumers as well as producers are controlled is to allow for larger variation in the power production due to the significant amount of renewable energy. The multiple power generators and consumers must be coordinated to balance the supply and demand for power at all times. The aim of this study is to examine a control technique for large scale distributed energy systems (DES), where a significant amount of renewable energy sources are present. Economic Model Predictive Control (MPC) is applied to control the power generators, minimizing the cost and producing the amount of energy required. We examine the large scale scenario, where multiple power generators and consumers such as e.g. electrical vehicles, heat pumps for domestic heating, and refrigeration and cooling systems must be controlled to balance the supply and demand for power. The system is very large scale. To address the large scale of the system and be able to compute the control decisions within a sample period, Dantzig-Wolfe decomposition is used for solution of the resulting linear program describing the Economic MPC of such systems. The controller obtained has been tested by simulations of a power portfolio system.

General information
State: Published
Contributors: Standardi, L., Edlund, K., Poulsen, N. K., Jørgensen, J. B.
Pages: 141
Publication date: 2012
A Dantzig-Wolfe Decomposition Algorithm for Linear Economic MPC of a Power Plant Portfolio

Future power systems will consist of a large number of decentralized power producers and a large number of controllable power consumers in addition to stochastic power producers such as wind turbines and solar power plants. Control of such large scale systems requires new control algorithms. In this paper, we formulate the control of such a system as an Economic Model Predictive Control (MPC) problem. When the power producers and controllable power consumers have linear dynamics, the Economic MPC may be expressed as a linear program and we apply Dantzig-Wolfe decomposition for solution of this linear program. The Dantzig-Wolfe decomposition algorithm for Economic MPC is tested on a simulated case study with a large number of power producers. The Dantzig-Wolfe algorithm is compared to a standard linear programming (LP) solver for the Economic MPC. Simulation results reveal that the Dantzig-Wolfe algorithm is faster than the standard LP solver and enables solution of larger problems.

General information
State: Published
Organisations: Center for Energy Resources Engineering, Department of Informatics and Mathematical Modeling, Scientific Computing, Mathematical Statistics
Contributors: Standardi, L., Edlund, K., Poulsen, N. K., Jørgensen, J. B.
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Electronic versions: DWhnew.pdf
Research output: Research - peer-review » Article in proceedings – Annual report year: 2012

Artificial Neural Network Based State Estimators Integrated into Kalmtool

In this paper we present a toolbox enabling easy evaluation and comparison of different filtering algorithms. The toolbox is called Kalmtool and is a set of MATLAB tools for state estimation of nonlinear systems. The toolbox now contains functions for Artificial Neural Network Based State Estimation as well as for DD1 filter and the DD2 filter, as well as functions for Unscented Kalman Filters and several versions of particle filters. The toolbox requires MATLAB version 7, but no additional toolboxes are required.

General information
State: Published
Organisations: Department of Electrical Engineering, Automation and Control, Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Bayramoglu, E., Ravn, O., Poulsen, N. K.
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Bibliographical note
Invited paper.
Beyond the CP-curve in Model-based Control of Wind Turbines

The importance of including dynamic inflow in the model used by the control algorithm is investigated in this contribution. A control setup consisting of a model predictive controller and an extended Kalman filter in conjunction with mechanisms to switch smoothly between partial and full load operation is presented. Results, obtained from high-fidelity simulations, with and without dynamic inflow taken into account by the model-based control setup, show that the inclusion of dynamic inflow is important when operating in conditions close to the rated wind. The presented control setup does not employ collective pitch actuation during partial load operation, for e.g. load mitigation purposes, otherwise dynamic inflow would have been seen to also be of importance for all wind speeds below the rated wind speed.

Control of Blood Glucose for People with Type 1 Diabetes: an In Vivo Study

Since continuous glucose monitoring (CGM) technology and insulin pumps have improved recent years, a strong interest in a closed-loop artificial pancreas for people with type 1 diabetes has arisen. Presently, a fully automated controller of blood glucose must face many challenges, such as daily variations of patient's physiology and lack of accuracy of glucose sensors. In this paper we design and discuss an algorithm for overnight closed-loop control of blood glucose in people with type 1 diabetes. The algorithm is based on Model Predictive Control (MPC). We use an offset-free autoregressive model with exogenous input and moving average (ARMAX) to model the patient. Observer design and a time-varying glucose reference signal improve robustness of the algorithm. We test the algorithm in two clinical studies conducted at Hvidovre Hospital. The first study took place overnight, and the second one took place during daytime. These trials demonstrate the importance of observer design in ARMAX models and show the possibility of stabilizing blood glucose during the night.
Control of Blood Glucose for People with Type 1 Diabetes: an In Vivo Study

General information
State: Published
Organisations: Center for Energy Resources Engineering, Scientific Computing, Department of Informatics and Mathematical Modeling, Mathematical Statistics, Copenhagen University Hospital
Contributors: Boiroux, D., Schmidt, S., Duun-Henriksen, A. K., Fræssing, L., Nørgaard, K., Madsbad, S., Skyggebjerg, O., Poulsen, N. K., Madsen, H., Jørgensen, J. B.
Publication date: 2012

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http://npcw17.imm.dtu.dk/
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Research output: Research › Sound/Visual production (digital) – Annual report year: 2012

Designing Trailing Edge Flaps of Wind Turbines using an Integrated Design Approach
In this paper designing a controller for trailing edge flaps (TEF) as well as optimizing its position on the wind turbine blade will be considered. An integrated design approach will be used to optimize both TEF placement and controller simultaneously. Youla parameterization will be used to parameterize the controller and the plant. The goal is to maximize blade root bending moments while minimizing actuator activity. An optimization with linear matrix inequalities (LMI) constraints will be used to optimize the H1 norm of the system.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Electrical Engineering, Automation and Control
Contributors: Mirzaei, M., Poulsen, N. K., Niemann, H. H.
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Detection of Parametric Roll on Ships
Recent years have shown several incidents with dramatic damage on container vessels caused by parametric resonance. When the resonance starts, the roll oscillation at a sub-harmonic frequency of the wave excitation may be completely unexpected. Timely warning about the onset of the resonance phenomenon could make the navigator change ship’s speed and heading, and these remedial actions could make the vessel escape the bifurcation. This chapter proposes non-parametric methods to detect the onset of parametric roll resonance. Theoretical conditions for parametric resonance are re-visited and signal-based methods are developed to detect its onset. Hypothesis testing is derived for the particular distribution of the indicators for resonance. Robustness is investigated by analyzing forced roll and disturbances in real weather conditions. The performance of the novel methods is demonstrated on experimental data from towing tank tests and data from a container ship passing an Atlantic storm.

General information
State: Published
Organisations: Department of Electrical Engineering, Automation and Control, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Galeazzi, R., Blanke, M., Poulsen, N. K.
Pages: 17-43
Publication date: 2012
Economic Model Predictive Control for Building Climate Control in a Smart Grid

Model Predictive Control (MPC) can be used to control a system of energy producers and consumers in a Smart Grid. In this paper, we use heat pumps for heating residential buildings with a floor heating system. We use the thermal capacity of the building to shift the electricity consumptions to periods with low energy prices. In this way the heating system of the house becomes a flexible power consumer in the Smart Grid. This scenario is relevant for systems with a significant share of stochastic energy producers, e.g., wind turbines, where the ability to shift power consumption according to production is crucial. We present a model for a house with a heat pump used for supplying thermal energy to a floor heating system. The model is a linear state space model and the resulting controller is an Economic MPC formulated as a linear program. The model includes forecasts of both weather and electricity price. Simulation studies demonstrate the capabilities of the proposed model and algorithm. Compared to traditional operation of heat pumps with constant electricity prices, the optimized operating strategy saves 25-33% of the electricity cost.

General information
State: Published
Organisations: Center for Energy Resources Engineering, Department of Informatics and Mathematical Modeling, Scientific Computing, Mathematical Statistics
Contributors: Halvgaard, R., Poulsen, N. K., Madsen, H., Jørgensen, J. B.
Number of pages: 6
Pages: 6175631
Publication date: 2012

Electric vehicle charge planning using Economic Model Predictive Control

Economic Model Predictive Control (MPC) is very well suited for controlling smart energy systems since electricity price and demand forecasts are easily integrated in the controller. Electric vehicles (EVs) are expected to play a large role in the future Smart Grid. They are expected to provide grid services, both for peak reduction and for ancillary services, by absorbing short term variations in the electricity production. In this paper the Economic MPC minimizes the cost of electricity consumption for a single EV. Simulations show savings of 50–60% of the electricity costs compared to uncontrolled charging from load shifting based on driving pattern predictions. The future energy system in Denmark will most likely be based on renewable energy sources e.g., wind and solar power. These green energy sources introduce stochastic fluctuations in the electricity production. Therefore, energy should be consumed as soon as it is produced to avoid the need for energy storage as this is expensive, limited and introduces efficiency losses. The Economic MPC for EVs described in this paper may contribute to facilitating transition to a fossil free energy system.

General information
State: Published
Organisations: Center for Energy Resources Engineering, Department of Informatics and Mathematical Modeling, Scientific Computing, Mathematical Statistics, Department of Electrical Engineering, Electric Components
Contributors: Halvgaard, R., Poulsen, N. K., Madsen, H., Jørgensen, J. B., Marra, F., Bondy, D. E. M.
Number of pages: 6
Publication date: 2012
Fault diagnosis of a Wind Turbine Rotor using a Multi-blade Coordinate Framework

Fault diagnosis of a wind turbine rotor is considered. The faults considered are sensor faults and blades mounted with a pitch offset. A fault at a single blade will result in asymmetries in the rotor, which can be applied for fault diagnosis. The diagnosis is derived by using the multiblade coordinate (MBC) transformation also known as the Coleman transformation together with active fault diagnosis (AFD). This transforms the setup from rotating to fixed frame coordinates. The rotor speed acts as the auxiliary input for the active diagnosis. The applied method take the varying rotor speed into account. Operation at different mean wind speeds is examined and it is discussed how to exploit the findings acquired by the investigation of the various faults.

General information
State: Published
Organisations: Department of Wind Energy, Aeroelastic Design, Department of Electrical Engineering, Automation and Control, Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Henriksen, L. C., Niemann, H. H., Poulsen, N. K.
Pages: 37-42
Publication date: 2012

Forecasting and decision-making in electricity markets with focus on wind energy

This thesis deals with analysis, forecasting and decision making in liberalised electricity markets. Particular focus is on wind power, its interaction with the market and the daily decision making of wind power generators. Among recently emerged renewable energy generation technologies, wind power has become the global leader in terms of installed capacity and advancement. This makes wind power an ideal candidate to analyse the impact of growing renewable energy generation capacity on the electricity markets. Furthermore, its present status of a significant supplier of electricity makes derivation of practically applicable tools for decision making highly relevant.

The main characteristics of wind power differ fundamentally from those of conventional thermal power. Its effective generation capacity varies over time and is directly dependent on the weather. This dependency makes future production uncertain and difficult to contract even on a day-to-day basis. Consequently decisions about market bids for next-day delivery are based on production forecasts which are bound to come with some uncertainty. Naturally markets that experience large scale integration of wind power are affected by these different characteristics. The thesis presents analyses of how this impact is realised in markets significantly penetrated by wind power. Due to its representation by forecasts in the supply curve, such predictions are used to describe their non-linear influence on the market prices.

Methods adequately accounting for this effect in models for day-ahead forecasting of the prices are also presented in the thesis. Prompted by the volatile behaviour of electricity markets, considerable focus has been on time-varying
and robust parameter estimates. The models derived are all based on well
know methods from the statistical literature.

The stochastic production of wind turbines prompts the need for alternative
methods for optimally bidding wind power to day-ahead markets. Such bidding
strategies are formulated in this thesis, which utilise the information provided
by the market models. Bids that maximise expected revenues are found
and the possibility of risk averse behaviour is discussed.

**General information**

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Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Jónsson, T., Pinson, P., Poulsen, N. K.
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**Publication information**

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phd269_TryggviJonsson.pdf
Research output: Research › Ph.D. thesis – Annual report year: 2012

**Individual Pitch Control Using LIDAR Measurements**

In this work the problem of individual pitch control of a variable-speed variable-pitch wind turbine in the full load region is
considered. Model predictive control (MPC) is used to solve the problem. However as the plant is nonlinear and time
varying, a new approach is proposed to simplify the optimization problem. Nonlinear dynamics of the wind turbine is
derived by combining blade element momentum (BEM) theory and first principle modeling of the flexible structure. Then
the nonlinear model of the system is linearized using Taylor series expansion around its operating points and a family of
linear models are obtained. The operating points are determined by LIDAR measurements both for the current and
predicted future operating points. The obtained controller is applied on a full complexity, high fidelity wind turbine model.
Finally simulation results show improved load reduction on out-of-plane blade root bending moments and a better transient
response compared to a benchmark PI individual pitch controller.

**General information**

State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics, Department of Wind
Energy, Aeroelastic Design, Department of Electrical Engineering, Automation and Control
Contributors: Mirzaei, M., Henriksen, L. C., Poulsen, N. K., Niemann, H. H., Hansen, M. H.
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Publication date: 2012

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**Modeling Smart Energy Systems for Model Predictive Control**

Integrating large amounts of renewable energy sources like wind and solar power introduces large uctuations in the power
production. Either this energy must be stored or consumed right away. Storage solutions are very expensive and not
applicable everywhere. So utilizing all of this green energy as it is produced requires a very exible and controllable power
consumption. Examples of controllable electric loads are heat pumps in buildings and Electric Vehicles (EVs) that are
expected to play a large role in the future danish energy system. These units in a smart energy system can potentially oer
exibility on a time scale ranging from seconds to several days by moving power consumption, exploiting thermal inertia or
battery storage capacity, respectively. Using advanced control algorithms these systems are able to reduce their own
electricity costs by planning ahead and moving consumption to periods with green and cheap electricity. This situation
occurs when there is a lot of excess wind power in the system which is re ected in the electricity price and in turn creates
In this paper a decentralized control strategy is investigated where prices indirectly influence the total power consumption of the smart energy systems connected to the power grid. Compared to a direct control strategy the complexity of the problem is reduced and decreases both the computation efforts and the need for communication. However, not only the current price, but a forecast of the expected future price should also be available in order for the individual units to plan ahead in the most feasible way. This is necessary since Economic MPCs do not respond to the absolute cost of electricity, but to variations of the price over the prediction horizon. Economic MPC is ideal for price responsive units where the model is known very well. Constraints and disturbance forecasts are straightforward to implement in the controller. MPC relies on the receding horizon principle, where a new optimal control signal is calculated at each time step for the prediction horizon. Only the optimal control signal at the current time step is implemented and consequently closed loop feedback is obtained. A generic model of an energy component is proposed in this paper, so the same Economic MPC framework can be used to design controllers for the different units. However, different signals and forecasts, e.g. weather forecasts and usage patterns, are used depending on the unit. The generic state space will be a discrete time state space model with hard input constraints and soft output constraints. For the considered energy systems there is usually a strict limit on the maximum available power, but the output, e.g. a temperature or an EV battery state of charge, can often be relaxed. The output constraints thus define a band of operation, that can be time varying, and the controller must keep the output within these limits in the cheapest possible way. In this paper the price forecast available by all units is assumed to be known and equal to the day-ahead elspot price from the Nordic electricity exchange market NordPool. The resulting electricity cost savings compared to an MPC with no price considerations are around 30-50% for the chosen units. In future work the price could be replaced by an intrahour price that is related to the deviation between the planned and the actual consumption. In this way all units are motivated to stick to the predicted consumption plan.

**General information**

State: Published
Organisations: Center for Energy Resources Engineering, Department of Informatics and Mathematical Modeling, Scientific Computing, Mathematical Statistics
Contributors: Halvgaard, R., Poulsen, N. K., Madsen, H., Jørgensen, J. B.
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**Model predictive control for a smart solar tank based on weather and consumption forecasts**

In this work the heat dynamics of a storage tank were modelled on the basis of data and maximum likelihood methods. The resulting grey-box model was used for Economic Model Predictive Control (MPC) of the energy in the tank. The control objective was to balance the energy from a solar collector and the heat consumption in a residential house. The storage tank provides heat in periods where there is low solar radiation and stores heat when there is surplus solar heat. The forecasts of consumption patterns were based on data obtained from meters in a group of single-family houses in Denmark. The tank can also be heated by electric heating elements if necessary, but the electricity costs of operating these heating elements should be minimized. Consequently, the heating elements should be used in periods with cheap electricity. It is proposed to integrate a price-sensitive control to enable the storage tank to serve a smart energy system in which flexible consumers are expected to help balance fluctuating renewable energy sources like wind and solar. Through simulations, the impact of applying Economic MPC shows annual electricity cost savings up to 25-30%.

**General information**

State: Published
Organisations: Center for Energy Resources Engineering, Department of Informatics and Mathematical Modeling, Scientific Computing, Mathematical Statistics, Department of Civil Engineering, Section for Building Physics and Services
Contributors: Halvgaard, R., Bacher, P., Perers, B., Andersen, E., Furbo, S., Jørgensen, J. B., Poulsen, N. K., Madsen, H.
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Model Predictive Control of a Nonlinear System with Known Scheduling Variable

Model predictive control (MPC) of a class of nonlinear systems is considered in this paper. We will use Linear Parameter Varying (LPV) model of the nonlinear system. By taking the advantage of having future values of the scheduling variable, we will simplify state prediction. Consequently the control problem of the nonlinear system is simplified into a quadratic programming. Wind turbine is chosen as the case study and we choose wind speed as the scheduling variable. Wind speed is measurable ahead of the turbine, therefore the scheduling variable is known for the entire prediction horizon.
Monitoring of a Wind Turbine Rotor using a Multi-blade Coordinate Framework
In this paper a method to detect asymmetric faults in a wind turbine rotor is presented. The paper describes how fault diagnosis using an observer-based residual generator approach is able to distinguish between the nominal and faulty case by the injection of e.g. a sinusoidal excitation signal into the system. In the case of a wind turbine, an excitation signal is automatically generated by the rotation of the rotor in a turbulent wind field. Using the multi-blade coordinate transformation, the detection of asymmetries in the rotor of the wind turbine is greatly improved.

Operation Design of Wind Turbines in Strong Wind Conditions
In order to reduce the impact on the electrical grid from the shutdown of MW wind turbines at wind speeds higher than the cut-out wind speed of 25 m/s, we propose in this paper to run the turbines at high wind speeds up to 40 m/s. Two different operation designs are made for both constant speed and variable speed pitch regulated wind turbines. The variable speed design is more suitable for wind turbines to run at very high wind speeds which can help the turbine braking system to stop the turbine at the new "cut-out" wind speed. Reference power, rotational speed and pitch angle have been designed optimally. In order to reduce the possible increased loading, fatigue due to the wind gusts, control strategies have been considered for both constant speed and variable speed pitch regulated wind turbines. The control study shows that the designed controllers can reduce the standard deviations efficiently for wind turbines at some selected wind high speeds.

Overnight Control of Blood Glucose in People with Type 1 Diabetes
In this paper, we develop and test a Model Predictive Controller (MPC) for overnight stabilization of blood glucose in people with type 1 diabetes. The controller uses glucose measurements from a continuous glucose monitor (CGM) and its
decisions are implemented by a continuous subcutaneous insulin infusion (CSII) pump. Based on a priori patient
information, we propose a systematic method for computation of the model parameters in the MPC. Safety layers improve
the controller robustness and reduce the risk of hypoglycemia. The controller is evaluated in silico on a cohort of 100
randomly generated patients with a representative intersubject variability. This cohort is simulated overnight with realistic
variations in the insulin sensitivities and needs. Finally, we provide results for the first tests of this controller in a real clinic.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Scientific Computing, Mathematical Statistics,
Department of Systems Biology, Center for Systems Microbiology, Center for Energy Resources Engineering, Horus ApS,
Copenhagen University Hospital
Contributors: Boiroux, D., Duun-Henriksen, A. K., Schmidt, S., Nørgaard, K., Madsbad, S., Skygggebjerg, O., Jensen, P. R.
, Poulsen, N. K., Madsen, H., Jørgensen, J. B.
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Robust Model Predictive Control of a Nonlinear System with Known Scheduling Variable and Uncertain Gain
Robust model predictive control (RMPC) of a class of nonlinear systems is considered in this paper. We will use Linear
Parameter Varying (LPV) model of the nonlinear system. By taking the advantage of having future values of the
scheduling variable, we will simplify state prediction. Because of the special structure of the problem, uncertainty is only in
the B matrix (gain) of the state space model. Therefore by taking advantage of this structure, we formulate a tractable
minimax optimization problem to solve robust model predictive control problem. Wind turbine is chosen as the case study
and we choose wind speed as the scheduling variable. Wind speed is measurable ahead of the turbine, therefore the
scheduling variable is known for the entire prediction horizon.

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Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics, Department of Electrical
Engineering, Automation and Control
Contributors: Mirzaei, M., Poulsen, N. K., Niemann, H. H.
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Robust Model Predictive Control of a Wind Turbine

In this work the problem of robust model predictive control (robust MPC) of a wind turbine in the full load region is considered. A minimax robust MPC approach is used to tackle the problem. Nonlinear dynamics of the wind turbine are derived by combining blade element momentum (BEM) theory and first principle modeling of the turbine flexible structure. Thereafter the nonlinear model is linearized using Taylor series expansion around system operating points. Operating points are determined by effective wind speed and an extended Kalman filter (EKF) is employed to estimate this. In addition, a new sensor is introduced in the EKF to give faster estimations. Wind speed estimation error is used to assess uncertainties in the linearized model. Significant uncertainties are considered to be in the gain of the system (B matrix of the state space model). Therefore this special structure of the uncertain system is employed and a norm-bounded uncertainty model is used to formulate a minimax model predictive control. The resulting optimization problem is simplified by semidefinite relaxation and the controller obtained is applied on a full complexity, high fidelity wind turbine model. Finally simulation results are presented. First a comparison between PI and robust MPC is given. Afterwards simulations are done for a realization of turbulent wind with uniform profile based on the IEC standard.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics, Department of Electrical Engineering, Automation and Control
Contributors: Mirzaei, M., Poulsen, N. K., Niemann, H. H.
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Electronic versions: prod11347976581927_mpc_acc.pdf
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Stochastic Model Predictive Control with Applications in Smart Energy Systems

In response to growing concerns related to environmental issues, limited resources and security of supply, the energy industry is changing. One of the most significant developments has been the penetration of renewable energy sources. In Denmark, the share of wind power generation is expected to cover more than 50% of the total consumption by 2050. Energy systems based on significant amounts of renewable energy sources are subject to uncertainties. To accommodate the need for model predictive control (MPC) of such systems, the effect of the stochastic effects on the constraints must be accounted for. In conventional MPC, the stochastic effects on the constraints is handled by constraint back-off and the MPC problem can still be solved by solution of either a linear program or a quadratic program. Treating the constraints as probabilistic constraints provides a more systematic approach to handle the stochastic effects on constraints. In this formulation, the MPC may be represented by a chance constrained mathematical program. The chance constraints allow a direct tradeoff between a certain (low) frequency of violating the constraints and a performance function (e.g. an economic loss function). This is convenient for energy systems, since some constraints are very important to satisfy with a high probability, whereas violation of others are less prone to have a large economic penalty. In MPC applications the control action is obtained by solving an optimization problem at each sampling instant. To make the controller applicable in real-time efficient and reliable algorithms are required. If the uncertainty is assumed to be Gaussian, the optimization problems associated with chance constrained (linear) MPC can be expressed as second order cone programming (SOCP) problems. In this paper, we show that tailored interior point algorithms are well suited to handle this type of problems. Namely, by utilizing structure-exploiting methods, we implement a special-purpose solver for control of smart energy systems. The solver is compared against general-purpose implementations. As a case study, we consider a system consisting of fuel-fired thermal power plants, wind farms and electric vehicles.

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Contributors: Sokoler, L. E., Edlund, K., Melbak, T., Poulsen, N. K., Madsen, H., Jørgensen, J. B.
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Publisher: Technical University of Denmark (DTU)
Editors: Jørgensen, J. B., Huusom, J. K., Sin, G.
Tuning of Controller for Type 1 Diabetes Treatment with Stochastic Differential Equations

People with type 1 diabetes need several insulin injections every day to keep their blood glucose level in the normal range and thereby avoiding the acute and long term complications of diabetes. One of the recent treatments consists of a pump injecting insulin into the subcutaneous layer combined with a continuous glucose monitor (CGM) frequently observing the glucose level. Automatic control of the insulin pump based on CGM observations would ease the burden of constant diabetes treatment and management. We have developed a controller designed to keep the blood glucose level in the normal range by adjusting the size of insulin infusions from the pump based on model predictive control (MPC). A clinical pilot study to test the performance of the MPC controller overnight was performed. The conclusion was that the controller relied too much on the local trend of the blood glucose level which is a problem due to the noise corrupted observations from the CGM. In this paper we present a method to estimate the optimal Kalman gain in the controller based on stochastic differential equation modeling. With this model type we could estimate the process noise and observation noise separately based on data from the rst clinical pilot study. In doing so we obtained a more robust control algorithm which is less sensitive to fluctuations in the CGM observations and rely more on the global physiological trend of the blood glucose level. Finally, we present the promising results from the second pilot study testing the improved controller.

General information
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Organisations: Department of Informatics and Mathematical Modeling, Scientific Computing, Mathematical Statistics, Department of Systems Biology, Center for Systems Microbiology, Center for Energy Resources Engineering, Horus ApS, Copenhagen University Hospital
Contributors: Duun-Henriksen, A. K., Boiroux, D., Schmidt, S., Skyggebjerg, O., Madsbad, S., Jensen, P. R., Jørgensen, J. B., Poulsen, N. K., Nørgaard, K., Madsen, H.
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Tuning SISO offset-free Model Predictive Control based on ARX models

In this paper, we present a tuning methodology for a simple offset-free SISO Model Predictive Controller (MPC) based on autoregressive models with exogenous inputs (ARX models). ARX models simplify system identification as they can be identified from data using convex optimization. Furthermore, the proposed controller is simple to tune as it has only one free tuning parameter. These two features are advantageous in predictive process control as they simplify industrial commissioning of MPC. Disturbance rejection and offset-free control is important in industrial process control. To achieve offset-free control in face of unknown disturbances or model-plant mismatch, integrators must be introduced in either the estimator or the regulator. Traditionally, offset-free control is achieved using Brownian disturbance models in the estimator. In this paper we achieve offset-free control by extending the noise model with a filter containing an integrator. This filter is a first order ARMA model. By simulation and analysis, we argue that it is independent of the parameterization of the underlying linear plant; while the tuning of traditional disturbance models is system dependent. Using this insight, we present MPC for SISO systems based on ARX models combined with the first order filter. We derive expressions for the closed-loop variance of the unconstrained MPC based on a state space representation in innovation form and use these expressions to develop a tuning procedure for the regulator. We establish formal equivalence between GPC and state space based off-set free MPC. By simulation we demonstrate this procedure for a third order system. The offset-free ARX MPC demonstrates satisfactory set point tracking and rejection of an unmeasured step disturbance for a simulated furnace with a long time delay.
Wind turbine control with constraint handling: a model predictive control approach

This study presents a wind turbine controller able to handle both hard and soft constraints, typically on actuators but also on other components of the wind turbine, if needed. An issue especially relevant during extreme events or for under-dimensioned actuators. The presented controller is based on model predictive control, a control method well suited for constraint handling. The performance of the presented controller during an extreme operating gust is compared to that of a proportional-integral controller with integrator anti-windup. Furthermore, the presented controller’s capability to operate in both partial and full load operation and to switch between the two modes of operation is demonstrated by additional test cases.

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Organisations: Department of Wind Energy, Aeroelastic Design, Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Henriksen, L. C., Hansen, M. H., Poulsen, N. K.
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Scopus rating (2017): CiteScore 3.99 SJR 1.416 SNIP 1.412
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Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.05 SJR 1.071 SNIP 1.188
Web of Science (2016): Impact factor 2.536
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 3.05 SJR 1.348 SNIP 1.459
Web of Science (2015): Impact factor 1.957
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 3.05 SJR 1.183 SNIP 1.531
Offset free tracking in Model Predictive Control requires estimation of unmeasured disturbances or the inclusion of an integrator. An algorithm for estimation of an unknown disturbance based on adaptive estimation with time varying forgetting is introduced and benchmarked against the classical disturbance modelling approach, where the system description is augmented by a disturbance state. The time varying forgetting renders the new approach less sensitive to the nature of the disturbance. By simulation we demonstrate that this algorithm is advantageous in case of infrequent step disturbances of any magnitude.
A Design Algorithm using External Perturbation to Improve Iterative Feedback Tuning Convergence

Iterative Feedback Tuning constitutes an attractive control loop tuning method for processes in the absence of process insight. It is a purely data driven approach for optimization of the loop performance. The standard formulation ensures an unbiased estimate of the loop performance cost function gradient, which is used in a search algorithm for minimizing the performance cost. A slow rate of convergence of the tuning method is often experienced when tuning for disturbance rejection. This is due to a poor signal to noise ratio in the process data. A method is proposed for increasing the data information content by introducing an optimal perturbation signal in the tuning algorithm. The theoretical analysis is supported by a simulation example where the proposed method is compared to an existing method for acceleration of the convergence by use of optimal prefilters.
A μ-Synthesis Approach to Robust Control of a Wind Turbine

The problem of robust control of a wind turbine is considered in this paper. A set of controllers are designed based on a 2 degrees of freedom linearized model of a wind turbine. An extended Kalman filter is used to estimate effective wind speed and the estimated wind speed is used to find the operating point of the wind turbine. Due to imprecise wind speed estimation, uncertainty in the obtained linear model is considered. Uncertainties in the drivetrain stiffness and damping parameters are also considered as these values are lumped parameters of a distributed system and therefore they include inherent uncertainties. We include these uncertainties as parametric uncertainties in the model and design robust controllers using the DK-iteration method. Based on estimated wind speed a pair of controllers are chosen and convex combination of their outputs is applied to the plant. The resulting set of controllers is applied on a full complexity simulation model and simulations are performed for stochastic wind speed according to relevant IEC standard.

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Contributors: Mirzaei, M., Niemann, H. H., Poulsen, N. K.
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Electronic versions: cdc_2011_ver_2.pdf
Closed-Loop and Semi Closed-Loop Strategies for Control of Blood Glucose in People with Type 1 Diabetes

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Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling, Mathematical Statistics, Center for Energy Resources Engineering
Contributors: Boiroux, D., Finan, D. A., Jørgensen, J. B., Poulsen, N. K., Madsen, H.
Publication date: 2011
Peer-reviewed: No
Electronic versions:
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Source: orbit
Research output: Research - peer-review » Article in proceedings – Annual report year: 2011

Constraint Handling within a Multi-blade Coordinate Framework of a Wind Turbine
In this paper the control of a horizontal axis pitch controlled wind turbine using Model Predictive Control is presented. The multi-blade coordinate transformation is utilized to turn the rotating frame time-varying system description into a time-invariant fixed frame system description. Constraints in the rotating frame of reference are not easily described in the fixed frame and a Model Predictive Control formulation accommodating this problem is presented. The presented method is tested with satisfactory results in a numerical simulation.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics, Automation and Control, Department of Electrical Engineering
Contributors: Henriksen, L. C., Poulsen, N. K., Niemann, H. H.
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Publisher: IEEE
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Research output: Research - peer-review » Article in proceedings – Annual report year: 2011

Detecting asymmetries in the rotor of a wind turbine using the multi-blade coordinate transformation

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Automation and Control, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Henriksen, L. C., Niemann, H. H., Poulsen, N. K.
Publication date: 2011
Detection of Oestrus and Lameness in Dairy Cows

This thesis describes studies conducted on the subject of detecting oestrus and lameness in dairy cows. The studies comprise methods of statistical change detection and model based diagnosis, respectively. In the case of statistical change detection the development of algorithms for a decision support system is based on identifying behaviour from patterns of normal and deviant behaviour. Signal processing combined with statistical methods, e.g. likelihood ratio tests, are utilized to correlate observed behaviours with normal and detect changes. Diagnosis includes data from the available population of animals in order to isolate patterns of behaviours outside the norm for individuals, while being robust to common disturbance factors. The research is based on methods from change detection and fault diagnosis. Fault diagnosis techniques are employed to reduce the false alarm ratio, and attempts are made to isolate events and artefacts in signals that otherwise can give rise to false alarms. For the model based diagnosis the diagnosis is generally done evaluating an estimated probability distribution against hypotheses about causes of change behaviour, e.g. oestrus or lameness. The models used for diagnosis are chosen to represent the behaviours. A quantized system description is used as a diagnostic model. This technique is based on automata theory. The methods are in most cases specified to take into account parameters specific to the differences between production systems. The development of these methods and algorithms is an interdisciplinary activity including methods from fault diagnosis, information technology and statistics.

DK-iteration robust control design of a wind turbine

The problem of robust control of a wind turbine is considered in this paper. A controller is designed based on a 2 degrees of freedom linearized model. An extended Kalman filter is used to estimate effective wind speed and the estimated wind speed is used to find the operating point of the wind turbine. Due to imprecise wind speed estimation, uncertainty in the obtained linear model is considered. Uncertainties in the drivetrain stiffness and damping parameters are also considered as these values are lumped parameters of a distributed system and therefore they include inherent uncertainties. We include these uncertainties as parametric uncertainties in the model and design a robust controller using DK-iteration method. The controller is applied on a full complexity simulation model and simulations are performed for wind speed step changes.
**H∞ Control of a Wind Turbine**

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- **Organisations:** Mathematical Statistics, Department of Informatics and Mathematical Modeling, Automation and Control, Department of Electrical Engineering
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  - EAWE_2011_paper_mmir.pdf
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  - http://duwind.tudelft.nl/onderzoek/kenniscentra/duwind/phd-seminar/

**Insulin Administration for People with Type 1 diabetes**

In this paper, we apply model predictive control (MPC) for control of blood glucose in people with type 1 diabetes. The two first control strategies are based on nonlinear model predictive control (NMPC). The first control strategy is based on meal announcement in advance, while the second one considers meal announcement at mealtimes only. They give a quantitative upper bound on the achievable control performance. The third control strategy is a feedforward-feedback control strategy. This strategy uses a time-varying setpoint to reduce the risk of hypoglycemia. The feedback controller computes the optimal basal insulin infusion rate. The feedforward controller consists of a bolus calculator. It computes the optimal bolus, along with the time-varying glucose setpoint. We test these three strategies on a virtual patient with type 1 diabetes. The numerical results demonstrate the robustness of the last control strategy with respect to changes in the model parameters and incorrect meal announcement.

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- **State:** Published
- **Organisations:** Scientific Computing, Department of Informatics and Mathematical Modeling, Mathematical Statistics, Center for Energy Resources Engineering
- **Contributors:** Boiroux, D., Finan, D. A., Poulsen, N. K., Madsen, H., Jørgensen, J. B.
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**Model predictive control of trailing edge flaps on a wind turbine blade**

Trailing edge flaps on wind turbine blades have been investigated for several years. Aero-servoelastic simulations carried out with different simulation tools, trailing edge flaps configurations and controller designs proved that trailing edge flaps are a suitable solution for reducing some of the wind turbine fatigue and extreme loads. This potential was confirmed with
wind tunnel tests made on blade sections with trailing edge flaps and on a scaled two-bladed wind turbine in a wind tunnel. The work presented in this thesis includes a full-scale test run on a Vestas V27 wind turbine equipped with three trailing edge flaps on one blade, located on DTU’s Risø Campus in Roskilde, Denmark.

This thesis is divided into three parts: the controller design, results from simulations, and results from the experiments.

The trailing edge flaps controller designed for this project is based on a frequency-weighted model predictive control, tuned in order to target only the flapwise blade root loads at the frequencies contributing the most to blade root fatigue damage (the 1P, 2P and 3P frequencies), and to avoid unnecessary wear and tear of the actuators at high frequencies. A disturbance model consisting in periodic disturbances at the rotor speed harmonic frequencies and a quasi-steady input disturbance is aggregated to an analytical model of a spinning blade with trailing edge flaps.

Simulations on a multi-megawatt wind turbine show the potential of the trailing edge flaps to reduce the flapwise blade root fatigue loads by 23%, but also the main shaft and the tower fatigue loads by up to 32%. Extreme loads during normal production also benefit from the trailing edge flaps.

At last, the same controller was run on the Vestas V27 wind turbine located at the Risø Campus of the Technical University of Denmark, in Roskilde, Denmark. One blade of the turbine was equipped with three independent trailing edge flaps. In spite of the failure of several sensors and actuators, the test of the trailing edge flaps controller described in this thesis showed a consistent flapwise blade root fatigue load reduction. An average of 14% load reduction was achieved during a 38 minute test. However, the experiment also highlighted the weaknesses of the controller. The trailing edge flap controller should be made more adaptive in order to cope with the very different wind conditions that can be expected on-site.
Noise Modelling and MPC Tuning for Systems with Infrequent Step Disturbances
In this paper, an offset-free SISO MPC implementation based on an ARX model of the system dynamics is investigated. Special emphasis is directed to achieving good closed loop performance for systems which may be step wised perturbed by a sustained, unmeasured disturbance. Hence a noise model which expresses the behaviour of this non-stationary noise process is sought. Tuning of the ARX-based MPC implementation is discussed and illustrated in a simulation example. Guidelines for tuning of the free parameters are presented.

Nonlinear Model Predictive Control of a Simplified Wind Turbine
In this paper, an offset-free SISO MPC implementation based on an ARX model of the system dynamics is investigated. Special emphasis is directed to achieving good closed loop performance for systems which may be step wised perturbed by a sustained, unmeasured disturbance. Hence a noise model which expresses the behaviour of this non-stationary noise process is sought. Tuning of the ARX-based MPC implementation is discussed and illustrated in a simulation example. Guidelines for tuning of the free parameters are presented.
Oestrus Detection in Dairy Cows from Activity and Lying Data using on-line Individual Models
Automated monitoring and detection of oestrus in dairy cows is attractive for reasons of economy in dairy farming. While high performance detection has been shown possible using high-priced progesterone measurements, detection results were less reliable when only low-cost sensor data were available. Aiming at improving detection scheme reliability with the use of low-cost sensor data, this study combines information from step count and leg tilt sensors. Introducing a lying balance for the individual animal, a novel change detection scheme is derived from observed distributions of the step count data and the lying balance. Detection and hypothesis testing are based on generalised likelihood ratio optimisation combined with time-wise joint probability windowing based on the duration of oestrus and oestrus intervals. It is shown to be essential that cow-specific parameters and test statistics are derived on-line from data to cope with behaviours of individuals. Performance is validated on 18 sequences of data where definite proof of prior oestrus was available in form of subsequent pregnancy. These data were extracted from data sequences from 44 dairy cows over an 8 months period. The results show sensitivity 88.9% and error rate 5.9 %, which is very satisfactory when only cheap sensor data are used.

General information
State: Published
Organisations: Automation and Control, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Aarhus University
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BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
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Scopus rating (2017): CiteScore 3.27 SJR 0.814 SNIP 1.563
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Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.27 SJR 0.873 SNIP 1.861
Web of Science (2016): Impact factor 2.201
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.99 SJR 0.816 SNIP 1.895
Web of Science (2015): Impact factor 1.892
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.71 SJR 0.961 SNIP 2.123
Web of Science (2014): Impact factor 1.761
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Scopus rating (2013): CiteScore 2.89 SJR 0.95 SNIP 2.345
Web of Science (2013): Impact factor 1.486
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Orchard navigation using derivative free Kalman filtering

This paper describes the use of derivative free filters for mobile robot localization and navigation in an orchard. The localization algorithm fuses odometry and gyro measurements with line features representing the surrounding fruit trees of the orchard. The line features are created on basis of 2D laser scanner data by a least square algorithm. The three derivative free filters are compared to an EKF based localization method on a typical run covering four rows in the orchard. The Matlab R toolbox Kalmtool is used for easy switching between different filter implementations without the need for changing the base structure of the system.

General information
State: Published
Organisations: Automation and Control, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Hansen, S., Bayramoglu, E., Andersen, J. C., Ravn, O., Andersen, N. A., Poulsen, N. K.
Pages: 4679-4684
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Host publication information
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Publisher: AACC
ISBN (Print): 978-1-4577-0080-4
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Keywords: Autonomous mobile robots, Sensor fusion, State estimation, Robot navigation, Localization
URLs:
Pre-Trained Neural Networks used for Non-Linear State Estimation

The paper focuses on nonlinear state estimation assuming non-Gaussian distributions of the states and the disturbances. The posterior distribution and the aposteriori distribution is described by a chosen family of paramtric distributions. The state transformation then results in a transformation of the parameters in the distribution. This transformation is approximated by a neural network using offline training, which is based on monte carlo sampling. In the paper, there will also be presented a method to construct a flexible distributions well suited for covering the effect of the non-linearities. The method can also be used to improve other parametric methods around regions with strong nonlinearities by including them inside the network.

General information
State: Published
Organisations: Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Bayramoglu, E., Andersen, N. A., Ravn, O., Poulsen, N. K.
Publication date: 2011

Host publication information
Title of host publication: The tenth International Conference on Machine Learning and Applications
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prod1132338553496.icmla2011_neural_state[1].pdf
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10.1109/ICMLA.2011.118
URLs:
http://www.icmla-conference.org/icmla11/
Source: orbit
Source-ID: 314533
Research output: Research - peer-review › Article in proceedings – Annual report year: 2011

Robust stability in constrained predictive control through the Youla parameterisations

In this article we take advantage of the primary and dual Youla parameterisations to set up a soft constrained model predictive control (MPC) scheme. In this framework it is possible to guarantee stability in face of norm-bounded uncertainties. Under special conditions guarantees are also given for hard input constraints. In more detail, we parameterise the MPC predictions in terms of the primary Youla parameter and use this parameter as the on-line optimisation variable. The uncertainty is parameterised in terms of the dual Youla parameter. Stability can then be guaranteed through small gain arguments on the loop consisting of the primary and dual Youla parameter. This is included in the MPC optimisation as a constraint on the induced gain of the optimisation variable. We illustrate the method with a numerical simulation example.

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling, Automation and Control, Department of Electrical Engineering
Contributors: Thomsen, S. C., Niemann, H. H., Poulsen, N. K.
Pages: 653-664
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Peer-reviewed: Yes

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Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.51 SJR 1.152 SNIP 1.237
Web of Science (2017): Impact factor 2.101
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BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.55 SJR 1.218 SNIP 1.382
Web of Science (2016): Impact factor 2.208
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.56 SJR 1.397 SNIP 1.357
Web of Science (2015): Impact factor 1.88
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.33 SJR 1.206 SNIP 1.408
Web of Science (2014): Impact factor 1.654
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 1.99 SJR 1.108 SNIP 1.248
Web of Science (2013): Impact factor 1.137
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 1.98 SJR 1.292 SNIP 1.408
Web of Science (2012): Impact factor 1.008
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 1.67 SJR 1.3 SNIP 1.337
Web of Science (2011): Impact factor 0.977
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.101 SNIP 1.39
Web of Science (2010): Impact factor 0.848
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.285 SNIP 1.518
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.182 SNIP 1.304
Scopus rating (2007): SJR 1.271 SNIP 1.446
Scopus rating (2006): SJR 1.168 SNIP 1.409
Scopus rating (2005): SJR 0.785 SNIP 1.283
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.233 SNIP 1.497
Scopus rating (2002): SJR 1.644 SNIP 1.469
Scopus rating (2001): SJR 1.622 SNIP 1.387
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.717 SNIP 1.466
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Original language: English
Keywords: Model Predictive Control, Youla parameterization, Robust control
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10.1080/00207179.2011.562923
Source: orbit
Source-ID: 257390
Strategies for glucose control in people with type 1 diabetes

In this paper we apply a robust feedforward-feedback control strategy to people with type 1 diabetes. The feedforward controller consists of a bolus calculator which compensates the disturbance coming from meals. The feedback controller is based on a linearized description of the model describing the patient. We minimize the risk of hypoglycemia by introducing a time-varying glucose setpoint based on the announced meal size and the physiological model of the patient. The simulation results are based on a virtual patient simulated by the Hovorka model. They include the cases where the insulin sensitivity changes, and mismatches in meal estimation. They demonstrate that the designed controller is able to achieve offset-free control when the insulin sensitivity change, and that having a time-varying reference signal enables more robust control of blood glucose in the cases where the meal size is known, but also when the ingested meal does not match the announced one.

Systematic identification and robust control design for uncertain time delay processes

A systematic procedure is proposed to handle the standard process control problem. The considered standard problem involves infrequent step disturbances to processes with large delays and measurement noise. The process is modeled as an ARX model and extended with a suitable noise model in order to reject unmeasured step disturbances and unavoidable model errors. This controller is illustrated to perform well for both set point tracking and a disturbance rejection for a SISO process example of a furnace which has a time delay which is significantly longer than the dominating time constant.
The achieved closed loop performance is therefore dependent on the quality of the future predictions. The performance of the state estimator is on the other hand dependent on the accuracy of the process and the noise model. Systems with long delays in the dynamic response between the actuators and the controlled variables are notoriously difficult to control or tune. A model predictive control implementation based on a model with the correct delay will provide good set-point tracking performance as long as the prediction horizon of the controller is longer than the delay. Hence a predictive controller would perform better in rejecting known disturbances and changes between operation modes than a PI controller with time-delay compensation as e.g. a Smith predictor. A common problem for all controllers, operating on a system with a delay longer than the dominating time constant, is that a stable system may reject small disturbances before the controller have an opportunity to act. If the controller is tuned to react on these minor disturbances the change in the actuator would lead to an increase in the variance of the system output. It is therefore desired if the controller does not react on minor disturbances or measurement noise. It is on the other hand important that the controller is not detuned such that significant or sustained disturbances cannot be effectively rejected. We proposed a model predictive control implementation with a dead-band on the penalty of the tracking error as a mean to achieve good closed loop performance on time delay system. We have in simulation tested our controller on a SISO system of an industrial furnace and a MIMO system on a cement grinding circuit.

General information
State: Published
Organisations: Computer Aided Process Engineering Center, Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Center for Energy Resources Engineering
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B., Jørgensen, J. B.
Publication date: 2011
Peer-reviewed: Yes
Source: orbit
Source-ID: 284483
Research output: Research - peer-review » Conference abstract for conference – Annual report year: 2011

An online re-linearization scheme suited for Model Predictive and Linear Quadratic Control
This technical note documents the equations for primal-dual interior-point quadratic programming problem solver used for MPC. The algorithm exploits the special structure of the MPC problem and is able to reduce the computational burden such that the computational burden scales with prediction horizon length in a linear way rather than cubic, which would be the case if the structure was not exploited. It is also shown how models used for design of model-based controllers, e.g. linear quadratic and model predictive, can be linearized both at equilibrium and non-equilibrium points, making the presented extension of the controller formulation equivalent to that of the extended Kalman filter compared to an ordinary Kalman filter.

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Henriksen, L. C., Poulsen, N. K.
Publication date: 2010

Publication information
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Publisher: Technical University of Denmark, DTU Informatics, Building 321
Edition: March 4, 2011, Rev. 2.
Original language: English
Keywords: Aeroelastic design methods, Wind Energy
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Source-ID: 267245
Research output: Research › Report – Annual report year: 2010

ARX-based Model Predictive Control of Systems with Time Delays

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Computer Aided Process Engineering Center, Center for Energy Resources Engineering
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B., Jørgensen, J. B.
ARX-Model based Model Predictive Control with Offset-Free Tracking

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Computer Aided Process Engineering Center, Scientific Computing, Center for Energy Resources Engineering
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B., Jørgensen, J. B.
Pages: 601-606
Publication date: 2010

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Volume: 28
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ISBN (Print): 04-44-53569-1
(Computer Aided Chemical Engineering).

ARX MPC for people with type 1 diabetes
Type 1 diabetes is a chronic disease characterized by a lack of production of pancreatic insulin, consequently leading to high blood glucose concentrations (hyperglycemia). Hyperglycemia has negative health effects in the long term such as eye, nerve, and kidney disease. Exogenous insulin must be injected to keep the blood glucose in the normoglycemic range (approximately 60 – 140 mg/dL, or 3.3 – 8 mmol/L). However, the dosing of exogenous insulin must be done carefully, because low blood glucose concentrations (hypoglycemia) can have immediate and severe consequences like insulin shock, coma, or even death. Currently, insulin administration is performed by the subject with type 1 diabetes based on infrequent glucose measurements (in the form of finger-sticks), often resulting in an unsatisfactory blood glucose control. An artificial pancreas is a medical device that injects exogenous insulin automatically in order to regulate the glucose concentration. Blood glucose measurements are obtained from a continuous glucose monitor (CGM). Insulin is administrated either continuously through an insulin pump, or at discrete times using an insulin pen. A control algorithm uses previous glucose measurements and insulin injection information to compute the optimal insulin administration for the current conditions. We use model predictive control (MPC) to compute the optimal insulin administration for 20 virtual type 1 diabetes subjects. The system (i.e., subject) has one manipulated input (insulin infusion rate), one disturbance input (carbohydrate meals), and one measured output (blood glucose concentration). The subject is represented by a system of nonlinear differential equations describing the dynamic effects of insulin and meals on blood glucose. Twenty parameter sets are used in the study, each representing a different virtual subject. The model used in the MPC is a low order autoregressive exogenous-input (ARX) model. Due to both the linearity and relative parsimony of the ARX model, there is a significant amount of subject/model mismatch in the model predictions, reflecting real-world conditions. In general, a simple ARX MPC cannot reject a step disturbance without a resulting offset; thus, the state vector is reformulated using an
extended ΔARX description (E-ΔARX). The reference signal is time-varying, and is based on the optimal open-loop glucose profile. Insulin-on-board constraints are implemented to avoid overdosing insulin. State estimation is based on a Kalman filter using the noise model to simulate a realistic CGM. We present the MPC results for simulations of the 20 virtual subjects with type 1 diabetes. In particular, we investigate the effects of the prediction horizon length on the control quality of blood glucose and the robustness of the solution.

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling, Mathematical Statistics, Center for Energy Resources Engineering
Contributors: Boiroux, D., Finan, D. A., Jørgensen, J. B., Poulsen, N. K., Madsen, H.
Publication date: 2010
Peer-reviewed: Yes
Keywords: Type 1 diabetes, ARX model, Model predictive control, Kalman filtering
Electronic versions:
Abstract2.pdf
Source: orbit
Source-ID: 262936
Research output: Research - peer-review › Conference abstract for conference – Annual report year: 2010

A Trust-region-based Sequential Quadratic Programming Algorithm
This technical note documents the trust-region-based sequential quadratic programming algorithm used in other works by the authors. The algorithm seeks to minimize a convex nonlinear cost function subject to linear inequality constraints and nonlinear equality constraints.

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Henriksen, L. C., Poulsen, N. K.
Publication date: 2010

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Place of publication: Kgs. Lyngby
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Research output: Research › Report – Annual report year: 2010

Control switching in high performance and fault tolerant control
The problem of reliability in high performance control and in fault tolerant control is considered in this paper. A feedback controller architecture for high performance and fault tolerance is considered. The architecture is based on the Youla-Jabr-Bongiorno-Kucera (YJBK) parameterization. By using the nominal controller in the architecture as a simple and robust controller, it is possible to use the YJBK transfer function for optimization of the closed-loop performance. This can be done both in connections with normal operation of the system as well as in connection with faults in the system. The architecture will also allow changing the applied sensors and/or actuators when switching between different controllers. This switching get particular simple for open-loop stable systems.

General information
State: Published
Organisations: Automation and Control, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Niemann, H. H., Poulsen, N. K.
Publication date: 2010

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Title of host publication: Proceedings of the 2010 American Control Conference, ACC 2010
ISBN (Print): 978-1-4244-7425-7
Keywords: Linear systems
**Derivative free filtering using Kalmtool**

In this paper we present a toolbox enabling easy evaluation and comparison of different filtering algorithms. The toolbox is called Kalmtool 4 and is a set of MATLAB tools for state estimation of nonlinear systems. The toolbox contains functions for extended Kalman filtering as well as for DD1 filter and the DD2 filter. It also contains functions for Unscented Kalman filters as well as several versions of particle filters. The toolbox requires MATLAB version 7, but no additional toolboxes are required.

**General information**

State: Published
Organisations: Department of Electrical Engineering, Automation and Control, Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Bayramoglu, E., Hansen, S., Ravn, O., Poulsen, N. K.
Publication date: 2010

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ISBN (Print): 978-0-9824438-1-1
Source: orbit
Source-ID: 265619
Research output: Research - peer-review › Article in proceedings – Annual report year: 2010

**Derivative free Kalman filtering used for orchard navigation**

In this paper the use of derivative free filters for mobile robot localisation is investigated. Three different filters are tested on real life data from an autonomous tractor running in an orchard environment. The localisation algorithm fuses odometry and gyro measurements with line features representing the surrounding fruit trees. The line features are created on basis of 2D laser scanner data by a least square algorithm. The Matlab (R) toolbox Kalmtool is used for easy switching between different filter implementations without the need for changing the base structure of the system.

**General information**

State: Published
Organisations: Department of Electrical Engineering, Automation and Control, Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Hansen, S., Bayramoglu, E., Andersen, J. C., Ravn, O., Andersen, N. A., Poulsen, N. K.
Publication date: 2010

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Title of host publication: Derivative free Kalman filtering used for orchard navigation
ISBN (Print): 978-0-9824438-1-1
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Research output: Research - peer-review › Article in proceedings – Annual report year: 2010

**Implications and Limitations of Ideal Insulin Administration for People with Type 1 Diabetes**

**General information**

State: Published
Organisations: Center for Energy Resources Engineering, Department of Informatics and Mathematical Modeling, Scientific Computing, Mathematical Statistics
Contributors: Boiroux, D., Finan, D. A., Jørgensen, J. B., Poulsen, N. K., Madsen, H.
Publication date: 2010

**Host publication information**

Title of host publication: UKACC International Conference on CONTROL 2010 proceedings
Electronic versions: UKACC2010.pdf
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Research output: Research - peer-review › Article in proceedings – Annual report year: 2010
**Meal Estimation in Nonlinear Model Predictive Control for Type 1 Diabetes**

**General information**
State: Published
Organisations: Center for Energy Resources Engineering, Department of Informatics and Mathematical Modeling, Scientific Computing, Mathematical Statistics
Contributors: Boiroux, D., Finan, D. A., Jørgensen, J. B., Poulsen, N. K., Madsen, H.
Pages: 1052-1057
Publication date: 2010

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Source-ID: 259673
Research output: Research - peer-review › Article in proceedings – Annual report year: 2010

**Nonlinear Model Predictive Control for an Artificial Beta-Cell**

**General information**
State: E-pub ahead of print
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling, Mathematical Statistics, Center for Energy Resources Engineering
Contributors: Boiroux, D., Finan, D. A., Jørgensen, J. B., Poulsen, N. K., Madsen, H.
Pages: 299-308
Publication date: 2010

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Publisher: Springer
Source: orbit
Source-ID: 259665
Research output: Research - peer-review › Book chapter – Annual report year: 2010

**Non-Linear State Estimation Using Pre-Trained Neural Networks**
This article presents a method to track non-Gaussian parametric probability density functions under nonlinear transformations and posterior calculations. The optimal set of parameters for the transformed distribution is a function of the parameters for the prior distribution and any other variables effecting the transformation. This function is approximated by a neural network using offline training. The training is based on monte carlo sampling. A way to obtain parametric distributions of flexible shape to be used easily with these networks is also presented. The method can also be used to improve other parametric methods around regions with strong non-linearities by including them inside the network.

**General information**
State: Published
Organisations: Automation and Control, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Optimal Insulin Administration for People with Type 1 Diabetes

The invention relates to methods for prediction of parametric rolling of vessels. The methods are based on frequency domain and time domain information in order to set up a detector able to trigger an alarm when parametric roll is likely to occur. The methods use measurements of e.g. pitch and roll oscillations and compare the measured oscillations using FFT analysis of signal correlations, variance analysis of signals and other comparisons. As an example, the presence of a growing peak around a frequency that doubles the roll natural frequency indicates the possibility that parametric roll is going to happen.

Prediction of resonant oscillation

The invention relates to methods for prediction of parametric rolling of vessels. The methods are based on frequency domain and time domain information in order to set up a detector able to trigger an alarm when parametric roll is likely to occur. The methods use measurements of e.g. pitch and roll oscillations and compare the measured oscillations using FFT analysis of signal correlations, variance analysis of signals and other comparisons. As an example, the presence of a growing peak around a frequency that doubles the roll natural frequency indicates the possibility that parametric roll is going to happen.

Results from the first full scale wind turbine equipped with trailing edge flaps

The invention relates to methods for prediction of parametric rolling of vessels. The methods are based on frequency domain and time domain information in order to set up a detector able to trigger an alarm when parametric roll is likely to occur. The methods use measurements of e.g. pitch and roll oscillations and compare the measured oscillations using FFT analysis of signal correlations, variance analysis of signals and other comparisons. As an example, the presence of a growing peak around a frequency that doubles the roll natural frequency indicates the possibility that parametric roll is going to happen.
Robust model identification applied to type 1 diabetes
In many realistic applications, process noise is known to be neither white nor normally distributed. When identifying models in these cases, it may be more effective to minimize a different penalty function than the standard sum of squared errors (as in a least-squares identification method). This paper investigates model identification based on two different penalty functions: the 1-norm of the prediction errors and a Huber-type penalty function. For data characteristic of some realistic applications, model identification based on these latter two penalty functions is shown to result in more accurate estimates of parameters than the standard least-squares solution, and more accurate model predictions for test data. The identification techniques are demonstrated on a simple toy problem as well as a physiological model of type 1 diabetes.

Robust stability in predictive control with soft constraints
In this paper we take advantage of the primary and dual Youla parameterizations for setting up a soft constrained model predictive control (MPC) scheme for which stability is guaranteed in face of norm-bounded uncertainties. Under special conditions guarantees are also given for hard input constraints. In more detail, we parameterize the MPC predictions in terms of the primary Youla parameter and use this parameter as the online optimization variable. The uncertainty is parameterized in terms of the dual Youla parameter. Stability can then be guaranteed through small gain arguments on the loop consisting of the primary and dual Youla parameter. This is included in the MPC optimization as a constraint on the induced gain of the optimization variable. We illustrate the method with a numerical simulation example.

Stochastic wind turbine control in multiblade coordinates
In this paper we consider wind turbine load attenuation through model based control. Asymmetric loads caused by the wind field can be reduced by pitching the blades individually. To this end we investigate the use of stochastic models of the wind which can be included in a model based individual pitch controller design. In this way the variability of the wind...
can be estimated and compensated for by the controller. The wind turbine model is in general time-variant due to its rotational nature. For this reason the modeling and control is carried out in so-called multiblade coordinates. A controller based on the H2 methodology is designed and tested in simulations.

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling, Automation and Control, Department of Electrical Engineering
Contributors: Thomsen, S. C., Niemann, H. H., Poulsen, N. K.
Publication date: 2010

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Keywords: Stochastic control, Wind turbine, Individual pitch control, Wind
Source: orbit
Source-ID: 257381
Research output: Research - peer-review › Article in proceedings – Annual report year: 2010

Tuning of ARX-based Model Predictive Control for Offset-free Tracking

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Computer Aided Process Engineering Center, Scientific Computing, Center for Energy Resources Engineering
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B., Jørgensen, J. B.
Publication date: 2010

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Location: Aachen, Germany
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Research output: Research › Sound/Visual production (digital) – Annual report year: 2010

Tuning of ARX-based Model Predictive Control for Offset-free Tracking

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Computer Aided Process Engineering Center, Scientific Computing, Center for Energy Resources Engineering
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B., Jørgensen, J. B.
Publication date: 2010

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Event: 16th Nordic Process Control Workshop
Location: Lund, Sweden
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Source-ID: 266289
Research output: Research › Sound/Visual production (digital) – Annual report year: 2010

Tuning of ARX-based Model Predictive Control for Offset-free Tracking

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Computer Aided Process Engineering Center, Scientific Computing, Center for Energy Resources Engineering
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B., Jørgensen, J. B.
Pages: 152-153
Publication date: 2010

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Tuning of ARX-based Model Predictive Control for Offset-free Tracking

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State: Published
Organisations: Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Computer Aided Process Engineering Center, Scientific Computing, Center for Energy Resources Engineering
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B., Jørgensen, J. B.
Publication date: 2010
Peer-reviewed: Yes
Source: orbit
Source-ID: 266269
Research output: Research - peer-review › Poster – Annual report year: 2010

Tuning of methods for offset free MPC based on ARX model representations

In this paper we investigate model predictive control (MPC) based on ARX models. ARX models can be identified from data using convex optimization technologies and is linear in the system parameters. Compared to other model parameterizations this feature is an advantage in embedded applications for robust and automatic system identification. Standard MPC is not able to reject a sustained, unmeasured, non zero mean disturbance and will therefore not provide offset free tracking. Offset free tracking can be guaranteed for this type of disturbances if Δ variables are used or if the state space is extended with a disturbance model state. The relation between the base case and the two extended methods are illustrated which provides good understanding and a platform for discussing tuning for good closed loop performance.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Computer Aided Process Engineering Center, Scientific Computing, Center for Energy Resources Engineering
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B., Jørgensen, J. B.
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Copyright 2010 IEEE. Personal use of this material is permitted. However, permission to reprint/republish this material for advertising or promotional purposes or for creating new collective works for resale or redistribution to servers or lists, or to reuse any copyrighted component of this work in other works must be obtained from the IEEE.
Source: orbit
Source-ID: 250523
Research output: Research - peer-review › Article in proceedings – Annual report year: 2010

Tuning of Offset-Free ARX-based SISO Model Predictive Control

General information
State: Submitted
Organisations: Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Computer Aided Process Engineering Center, Scientific Computing, Center for Energy Resources Engineering
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B., Jørgensen, J. B.
Publication date: 2010
A Concept for fault tolerant controllers

This paper describes a concept for fault tolerant controllers (FTC) based on the YJBK (after Youla, Jabr, Bongiorno and Kucera) parameterization. This controller architecture will allow to change the controller on-line in the case of faults in the system. In the described FTC concept, a safe mode controller is applied as the basic feedback controller. A controller for normal operation with high performance is obtained by including certain YJBK parameters (transfer functions) in the controller. This will allow a fast switch from normal operation to safe mode operation in case of critical faults in the system. The described FTC architecture allow the different feedback controllers to apply different sets of sensors and actuators.

Active Fault Diagnosis - A Stochastic Approach

Active Fault Diagnosis for Systems with Reduced Model Information
Active Fault Isolation and Estimation

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling, Automation and Control, Department of Electrical Engineering
Contributors: Poulsen, N. K., Niemann, H. H.
Number of pages: 306
Pages: 151-158
Publication date: 2009

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Place of publication: Gdansk
Publisher: Pomerian Science and Technology Publishers
ISBN (Print): 9788392680635
Source: orbit

Active system monitoring applied on wind turbines
A concept for active system monitoring (ASM) applied on wind turbines is presented in this paper. The concept is based on an injection of a small periodic auxiliary signal in the system. An investigation of the signature from the auxiliary input in residual (error) signals can then be applied for an online monitoring of central parameters/elements of the system. Statistical tests are applied on the residual signals for obtaining a correct monitoring.

General information
State: Published
Organisations: Automation and Control, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Technical University of Denmark
Contributors: Niemann, H. H., Poulsen, N. K., Parbo, H., Nielsen, M. L.
Publication date: 2009

Host publication information
Title of host publication: Proceedings od Nordic Wind Power Conference 2009
Keywords: Wind turbines, system monitoring, active diagnosis, statistical tests
Source: orbit

Adaptive Disturbance Estimation for Offset-Free Model Predictive Control

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Computer Aided Process Engineering Center, Scientific Computing
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B., Jørgensen, J. B.
Publication date: 2009

Publication information
Publisher: Technical University of Denmark (DTU)
Original language: English
Source: orbit

Attenuating wind turbine loads through model based individual pitch control
In this paper we consider wind turbine load attenuation through model based control. Asymmetric loads caused by the wind field can be reduced by pitching the blades individually. To this end we investigate the use of stochastic models of the wind which can be included in a model based individual pitch controller design. In this way the variability of the wind can be estimated and compensated for by the controller. The wind turbine model is in general time-variant due to its
rotational nature. For this reason the modeling and control is carried out in so-called multiblade coordinates. The individual pitch controller design in investigated in simulations.

**General information**

State: Published  
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics, Department of Electrical Engineering, Automation and Control  
Contributors: Thomsen, S. C., Niemann, H. H., Poulsen, N. K.  
Publication date: 2009

**Host publication information**

Title of host publication: Proceedings of Nordic Wind Power Conference 2009  
Keywords: Wind turbine, Control, Load reduction  
Source: orbit  
Source-ID: 250191  
Research output: Research › Article in proceedings – Annual report year: 2009

**Combination of activity and lying/standing data for detection of oestrus in cows**

The objective of this study is to develop an algorithm for detecting oestrus in dairy cows from measurements of activity and duration of lying/standing periods. Each cows activity is measured by a sensor attached to the neck that returns an activity index for each hour. Duration of lying is measured by a sensor attached to the hind leg of the cow. Activity and lying/standing behaviour are modelled as a discrete event system, constructed using automata theory. In an attempt to estimate a biologically relevant lying balance, a lying balance indicator is constructed and is influencing transition probabilities in the stochastic automata. The cows lying-balance indicates how much the cow has been resting during the immediately past period, and the balance express to the automata, the tendency of the cow to continue resting or not. Automata for describing the two scenarios; normal and oestrus are designed and results of decision algorithms are presented for Oestrus detection. Detection based on the lying balance indicator and the two sets of measured information are demonstrated to increase the detection sensitivity to 100% for a set of 10 cows.

**General information**

State: Published  
Organisations: Automation and Control, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Aarhus University  
Contributors: Jónsson, R. I., Blanke, M., Poulsen, N. K., Munksgaard, L., Højsgaard, S.  
Pages: 207-214  
Publication date: 2009

**Host publication information**

Title of host publication: Precision livestock farming '09  
Keywords: animal monitoring  
Source: orbit  
Source-ID: 242344  
Research output: Research - peer-review › Article in proceedings – Annual report year: 2009

**Comparing mobile robot localisation algorithms using Kalmtool**

In this paper we present an estimation platform with simulation capabilities to evaluate methods for localisation of a mobile robot using a feature map. The platform is based on the Kalmtool 4 toolbox which is a set of MATLAB tools for state estimation of nonlinear systems. The toolbox contains functions for extended Kalman filtering as well as for the DD1 filter and the DD2 filter. It also contains functions for Unscented Kalman filters as well as three versions of particle filters. The toolbox requires MATLAB version 7, but no additional toolboxes are required.

**General information**

State: Published  
Organisations: Automation, Department of Electrical Engineering, Automation and Control, Mathematical Statistics, Department of Informatics and Mathematical Modeling  
Contributors: Mogensen, L. V., Hansen, S., Ravn, O., Poulsen, N. K.  
Publication date: 2009

**Host publication information**

Title of host publication: Proceeding of 15th IFAC Symposium on System Identification, SYSID 2009  
Source: orbit  
Source-ID: 247928  
Research output: Research - peer-review › Article in proceedings – Annual report year: 2009
Controller Architectures for Switching

This paper investigates different controller architectures in connection with controller switching. The controller switching is derived by using the Youla-Jabr-Bongiorno-Kucera (YJBK) parameterization. A number of different architectures for the implementation of the YJBK parameterization are described and applied in connection with controller switching. An architecture that does not include inversion of the coprime factors is introduced. This architecture will make controller switching particularly simple.

General information
State: Published
Organisations: Automation and Control, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Niemann, H. H., Poulsen, N. K.
Pages: 1098-1103
Publication date: 2009

Host publication information
Title of host publication: American Control Conference, Final Program and book of Abstracts
Publisher: IEEE
ISBN (Print): 978-1-4244-4523-3
Electronic versions:
Niemann.pdf
DOIs: 10.1109/ACC.2009.5160113

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Source: orbit
Source-ID: 251825
Research output: Research - peer-review › Conference abstract in proceedings – Annual report year: 2009

Data Driven Tuning of State Space Controllers with Observes

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Computer Aided Process Engineering Center
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B.
Publication date: 2009

Event information
Event: European Control Conference 2009
Location: Budapest, Hungary
Source: orbit
Source-ID: 248702
Research output: Research › Sound/Visual production (digital) – Annual report year: 2009
Data Driven Tuning of State Space Control loops with unknown state information and model uncertainty

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Computer Aided Process Engineering Center
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B.
Pages: 441-446
Publication date: 2009

Host publication information
Title of host publication: Computer-Aided Chemical Engineering Series
Volume: 26
Publisher: Elsevier
Source-ID: 229341
Research output: Research - peer-review › Article in proceedings – Annual report year: 2009

Detection of Parametric Roll Resonance on Ships from Indication of Nonlinear Energy Flow

The detection of the onset of parametric roll resonance on ships is of a central importance in order to activate specific control strategies able to counteract the large roll motion. One of the main priorities is to have detectors with a small detection time, such that warnings can be issued when the roll oscillations are about 5°. This paper proposes two different detection approaches: the first one based on sinusoidal detection in white gaussian noise; the second one utilizes an energy flow indicator in order to catch the onset of parametric roll based upon the transfer of energy from heave and pitch to roll. Both detectors have been validated against experimental data of a scale model of a container vessel excited with both regular and irregular waves. The detector based on the energy flow indicator proved to be very robust to different scenarios (regular/irregular waves) since it does not rely on any specific assumption on the signal to be detected.

General information
State: Published
Organisations: Automation and Control, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Galeazzi, R., Blanke, M., Poulsen, N. K.
Pages: 348-353
Publication date: 2009

Host publication information
Title of host publication: Proceedings 7. IFAC Symposium on Fault Detection, Supervision and Safety of Technical Processes
ISBN (Print): 978-3-902661-46-3
Keywords: Roll resonance, Marine systems, Marine applications, Parametric resonance, Statistical methods
DOIs: 10.3182/20090630-4-ES-2003.00058
Source-ID: 246429
Research output: Research - peer-review › Article in proceedings – Annual report year: 2009
DiaCon: an interdisciplinary approach to diabetes control

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling, Mathematical Statistics, Center for Systems Microbiology, Department of Systems Biology
Contributors: Finan, D. A., Duun-Christensen, A. K., Schmidt, S., Boiroux, D., Jørgensen, J. B., Nørgaard, K., Jensen, P. R., Poulsen, N. K., Madsen, H.
Publication date: 2009
Peer-reviewed: Yes
Source: orbit
Source-ID: 257648
Research output: Research - peer-review › Poster – Annual report year: 2009

Energy-based nonlinear control of hydraulically actuated pitch-servo systems

General information
State: Published
Organisations: Aeroelastic Design, Wind Energy Division, Risø National Laboratory for Sustainable Energy, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Henriksen, L. C., Poulsen, N. K.
Publication date: 2009

Host publication information
Title of host publication: EWEC 2009 Proceedings online
Publisher: EWEC
Keywords: Wind energy, Aeroelastic Design
Electronic versions:
2009_24.pdf
Source: orbit
Source-ID: 241179
Research output: Research › Article in proceedings – Annual report year: 2009

Fault tolerant control - a residual based set-up
A new set-up for fault tolerant control (FTC) for stable systems is presented in this paper. The new set-up is based on a simple implementation of the Youla-Jabr-Bongiorno-Kucera (YJBK) parameterization. This implementation of the YJBK parameterization will allow a direct and simple reconfiguration of the feedback controller. Another central part of fault tolerant control is fault diagnosis. The controller implementation can be applied directly in connection with both passive diagnosis (PFD) as well as with active fault diagnosis (AFD). The presented FTC set-up is investigated with respect to sensor reconfiguration. Actuator reconfiguration can be dealt with in a similar way.

General information
State: Published
Organisations: Automation and Control, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Niemann, H. H., Poulsen, N. K.
Pages: 8470-8475
Publication date: 2009

Host publication information
Title of host publication: Proceedings of the 48th IEEE Conference on Decision and Control, 2009 held jointly with the 2009 28th Chinese Control Conference. CDC/CCC 2009
Publisher: IEEE
Edition: 1
ISBN (Print): 978-1-4244-3872-3
Keywords: controller architecture, feedback control, Fault tolerant control
Electronic versions:
Niemann.pdf
DOIs:
10.1109/CDC.2009.5400876

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Glucose modeling and prediction using physical activity variables

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Finan, D. A., Nørgaard, K., Bengtsson, H., Poulsen, J. U., Jørgensen, J. B., Poulsen, N. K., Madsen, H.
Publication date: 2009
Peer-reviewed: Yes
Event: Poster session presented at Diabetes Technology Meeting, .
Source: orbit

Improvements to least-squares model identification: an application to diabetes modeling

General information
State: Published
Organisations: Scientific Computing, Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Finan, D. A., Jørgensen, J. B., Poulsen, N. K., Madsen, H.
Publication date: 2009

Event information
Event: 2009 AIChE Annual Meeting
Location: Nashville, TN, United States
URLs: http://www.aiche.org/Conferences/AnnualMeeting/index.aspx
Source: orbit

Improving Convergence of Iterative Feedback Tuning

General information
State: Published
Organisations: Computer Aided Process Engineering Center, Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B.
Pages: 570-578
Publication date: 2009
Peer-reviewed: Yes

Publication information
Journal: Journal of Process Control
Volume: 19
Issue number: 4
ISSN (Print): 0959-1524
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 3.85 SJR 1.108 SNIP 1.971
Web of Science (2017): Impact factor 2.787
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Interconnection of subsystems in closed-loop systems

The focus in this paper is analysis of stability and controller design for interconnected systems. This includes both the case with known and unknown interconnected sub-system. The key element in both the stability analysis and controller...
design is the application of the Youla-Jabr-Bongiomo-Kucera (YJBK) parameterization. The dual YJBK transfer function is applied in connection with the closed-loop stability analysis. The primary YJBK parameterization is applied in connection with design of controllers. Further, it is shown how it is possible to obtain a direct estimation of a connected sub-system without having a direct access to it.

**General information**

State: Published
Organisations: Automation and Control, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Niemann, H. H., Poulsen, N. K.
Pages: 632-637
Publication date: 2009

**Host publication information**

Title of host publication: Proceedings of the 48th IEEE Conference on Decision and Control, 2009 held jointly with the 2009 28th Chinese Control Conference. CDC/CCC 2009
Publisher: IEEE
ISBN (Print): 978-1-4244-3872-3
Keywords: controller architecture, dynamic systems, stability, interconnected systems, Linear systems
Electronic versions: Niemann.pdf
DOIs: 10.1109/CDC.2009.5400817

**Bibliographical note**

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Source: orbit
Source-ID: 256272
Research output: Research - peer-review › Article in proceedings – Annual report year: 2009
Kalmtool used for laser scanner aided navigation in orchard

This paper concerns localisation of an autonomous tractor in an orchard environment, with the purpose of designing a localisation solution to be compared with GPS. The localisation is based on an estimate found by an extended Kalman filter, which fuses measurements from encoders and gyro with row measurements provided by a laser scanner. Kalmtool is used as a toolbox for developing the localisation algorithm. The result shows that the toolbox can be used successfully for dealing with localisation and sensor fusion.

General information
State: Published
Organisations: Automation, Department of Electrical Engineering, Automation and Control, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Mogensen, L. V., Hansen, S., Andersen, J. C., Ravn, O., Andersen, N. A., Blanke, M., Poulsen, N. K.
Publication date: 2009

Host publication information
Title of host publication: Proceeding of 15. IFAC Symposium on System Identification, SYSID 2009
Keywords: Bayesian Methods, Toolboxes
DOIs:
10.3182/20090706-3-FR-2004.00127
Source: orbit
Source-ID: 247934
Research output: Research - peer-review › Article in proceedings – Annual report year: 2009

Mobile Robot Navigation in a Corridor Using Visual Odometry

Incorporation of computer vision into mobile robot localization is studied in this work. It includes the generation of localization information from raw images and its fusion with the odometric pose estimation. The technique is then implemented on a small mobile robot operating at a corridor environment. A new segmented Hough transform with an improved way of discretization is used for image line extraction. The vanishing point concept is then incorporated to classify lines as well as to estimate the orientation. A method involving the iterative elimination of the outliers is employed to find both the vanishing point and the camera position. The fusion between the vision based pose estimation and the odometry is achieved with an extended Kalman filter. A distance driven error model is used for the odometry while a simple error model with constant noise is assumed for the vision. An extended Kalman filter as a parameter estimator is also applied to estimate odometry parameters. Experimental results are included. The robustness and the precision of the entire system is illustrated by performing simple navigation tasks.

General information
State: Published
Organisations: Automation and Control, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Bayramoglu, E., Andersen, N. A., Poulsen, N. K., Andersen, J. C., Ravn, O.
Pages: 58
Publication date: 2009

Host publication information
Title of host publication: Proceedings of the 14th International Conference on Advanced Robotics
Publisher: IEEE
Keywords: Line Extraction, Vision, Sensor Fusion, Localization, Navigation, Mobile Robot
Electronic versions:
CorridorVisualodo.pdf

Bibliographical note
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Source: orbit
Source-ID: 248417
Research output: Research - peer-review › Article in proceedings – Annual report year: 2009

Oestrus Detection in Dairy Cows using Automata Modelling and Diagnosis Techniques

This paper addresses detection of oestrus in dairy cows using automata-based modelling and diagnosis. Measuring lying/standing behaviour of the cows by a sensor attached to the cows hindleg, lying/standing behaviour is modelled as a stochastic automation. The paper introduces a cow’s lying-balance as a biologically inspired quantity describing how much the cow has been resting for a preceding period. A dynamic lying-balance model is identified from real data and the lying
balance is used as input, together with lying/standing sensor measurements. Using different automata models for oestrus and non-oestrus conditions, with state transition probability densities identified from observations, diagnosis theory for stochastic automata is employed to obtain diagnoses of oestrus. The oestrus cases are detected using consistency based diagnosis on real data.

**General information**
State: Published
Organisations: Automation and Control, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Jónsson, R. I., Caponetti, F., Blanke, M., Poulsen, N. K.
Pages: 1402-1407
Publication date: 2009

**Host publication information**
Title of host publication: Proceedings of 7. IFAC Symposium on Fault Detection, Supervision and Safety of Technical Processes
ISBN (Print): 978-3-902661-46-3
Keywords: Health monitoring, Diagnosis, Signal processing, Animal husbandry, Stochastic automata, Fault diagnosis and monitoring
DOIs: 10.3182/20090630-4-ES-2003.00228
Source: orbit
Source-ID: 242341
Research output: Research - peer-review › Article in proceedings – Annual report year: 2009

**Parametric Roll Resonance Detection using Phase Correlation and Log-likelihood Testing Techniques**
Real-time detection of parametric roll is still an open issue that is gathering an increasing attention. A first generation warning systems, based on guidelines and polar diagrams, showed their potential to face issues like long-term prediction and risk assessment. This paper presents a second generation warning system the purpose of which is to provide the master with an onboard system able to trigger an alarm when parametric roll is likely to happen within the immediate future. A detection scheme is introduced, which is able to issue a warning within five roll periods after a resonant motion started. After having determined statistical properties of the signals at hand, a detector based on the generalised log-likelihood ratio test (GLRT) is designed to look for variation in signal power. The ability of the detector to trigger alarms when parametric roll is going to onset is evaluated on two sets of experimental data, covering both regular and irregular seas in a model basin.

**General information**
State: Published
Organisations: Automation and Control, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Galeazzi, R., Blanke, M., Poulsen, N. K.
Pages: 316-321
Publication date: 2009

**Host publication information**
Title of host publication: Proceedings 8. IFAC International Conference on Manoeuvring and Control of Marine Craft : MCMC'2009
Keywords: Information systems and methods, Roll damping
DOIs: 10.3182/20090916-3-BR-3001.00051

**Bibliographical note**
This paper received the Best Regular Paper Award at MCMC'2009
Source: orbit
Source-ID: 250391
Research output: Research - peer-review › Article in proceedings – Annual report year: 2009

**Perturbed Iterative Feedback Tuning**

**General information**
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Computer Aided Process Engineering Center
Contributors: Huusom, J. K., Hjalmarsson, H., Poulsen, N. K., Jørgensen, S. B.
Publication date: 2009
Set point control in the state space setting
This report is intended as a supplement or an extension to the material used in connection to or after the courses Stochastic Adaptive Control (02421) and Static and Dynamic Optimization (02711) given at the Department of Informatics and Mathematical Modelling, The Technical University of Denmark. The focus is in this report related to the problem of handling a set point or a constant reference in a state space setting. In principle just about any (state space control) design methodology may be applied. Here the presentation is based on LQ design, but other types such as poleplacement can be applied as well. This is the Monte Petriolo paper which is a compilation of results gathered from the literature. A major part of the results are collected from the basic control literature during a sabbatical year at Oxford university and is further compiled and reported in Monte Petriolo (Umbria, Italy).

Stochastic wind turbine modeling for individual pitch control
By pitching the blades of a wind turbine individually it is possible to attenuate the asymmetric loads caused by a non-uniform wind field - this is denoted individual pitch control. In this work we investigate how to set up a simplified stochastic and deterministic description of the wind and a simplified description of the aerodynamics with sufficient detail to design model-based individual pitch controllers. Combined with a simplified model of the wind turbine, we exemplify how to use the model elements to systematically design an individual pitch controller. The design is investigated in simulations.

Temperature prediction at critical points in district heating systems

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Pinson, P., Nielsen, T. S., Nielsen, H. A., Poulsen, N. K., Madsen, H.
Pages: 163-176
Publication date: 2009
Identification for Control: Developments in the Iterative Feedback Tuning Framework

A Design Algorithm using External Perturbation to Improve Iterative Feedback Tuning Convergence
Active fault diagnosis based on stochastic tests
The focus of this paper is on stochastic change detection applied in connection with active fault diagnosis (AFD). An auxiliary input signal is applied in AFD. This signal injection in the system will in general allow us to obtain a fast change detection/isolation by considering the output or an error output from the system. The classical cumulative sum (CUSUM) test will be modified with respect to the AFD approach applied. The CUSUM method will be altered such that it will be able to detect a change in the signature from the auxiliary input signal in an (error) output signal. It will be shown how it is possible to apply both the gain and the phase change of the output signal in CUSUM tests. The method is demonstrated using an example.

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling, Automation, Department of Electrical Engineering
Contributors: Poulsen, N. K., Niemann, H. H.
Pages: 487-496
Publication date: 2008
Peer-reviewed: Yes

Publication information
Journal: International Journal of Applied Mathematics and Computer Science
Volume: 18
Issue number: 4
ISSN (Print): 1641-876X
Ratings:
Web of Science (2019): Indexed yes
Web of Science (2018): Indexed yes
Scopus rating (2017): CiteScore 2.2 SJR 0.729 SNIP 1.604
Web of Science (2017): Impact factor 1.694
Web of Science (2017): Indexed yes
Scopus rating (2016): CiteScore 1.81 SJR 0.47 SNIP 1.406
Web of Science (2016): Impact factor 1.42
Scopus rating (2015): CiteScore 2.13 SJR 0.71 SNIP 1.589
Web of Science (2015): Impact factor 1.037
Scopus rating (2014): CiteScore 2.03 SJR 0.632 SNIP 1.729
Web of Science (2014): Impact factor 1.227
Scopus rating (2013): CiteScore 2.07 SJR 0.71 SNIP 1.604
Web of Science (2013): Impact factor 1.39
ISI indexed (2013): ISI indexed yes
Scopus rating (2012): CiteScore 1.58 SJR 0.445 SNIP 1.379
Web of Science (2012): Impact factor 1.008
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
Scopus rating (2011): CiteScore 1.17 SJR 0.299 SNIP 1.122
Web of Science (2011): Impact factor 0.487
ISI indexed (2011): ISI indexed no
Web of Science (2011): Indexed yes
Scopus rating (2010): SJR 0.385 SNIP 1.229
Web of Science (2010): Impact factor 0.794
Scopus rating (2009): SJR 0.344 SNIP 1.414
Scopus rating (2008): SJR 0.294 SNIP 1.929
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.423 SNIP 1.364
Scopus rating (2005): SJR 0.122 SNIP 4.5
Scopus rating (2004): SJR 0.111 SNIP 0
Scopus rating (2003): SJR 0.11 SNIP 0
A Generalized Autocovariance Least-Squares Method for Kalman Filter Tuning

This paper discusses a method for estimating noise covariances from process data. In linear stochastic state-space representations the true noise covariances are generally unknown in practical applications. Using estimated covariances a Kalman filter can be tuned in order to increase the accuracy of the state estimates. There is a linear relationship between covariances and autocovariance. Therefore, the covariance estimation problem can be stated as a least-squares problem, which can be solved as a symmetric semidefinite least-squares problem. This problem is convex and can be solved efficiently by interior-point methods. A numerical algorithm for solving the symmetric is able to handle systems with mutually correlated process noise and measurement noise. (c) 2007 Elsevier Ltd. All rights reserved.
Ecogrid.dk Phase 1 WP4 report: New measures for integration of large scale renewable energy

General information
State: Published
Publication date: 2008

Publication information
Publisher: Danmarks Tekniske Universitet, Risø Nationallaboratoriet for Bæredygtig Energi
Original language: English
Electronic versions:
EcoGrid.dk - WP4 Report Measures.pdf
Source: orbit
Source-ID: 224237
Research output: Research › Report – Annual report year: 2008
Estimation of Model Uncertainties in Closed-loop Systems
This paper describes a method for estimation of parameters or uncertainties in closed-loop systems. The method is based on an application of the dual YJBK (after Youla, Jabr, Bongiorno and Kucera) parameterization of all systems stabilized by a given controller. The dual YJBK transfer function is a measure for the variation in the system seen through the feedback controller. It is shown that it is possible to isolate a certain number of parameters or uncertain blocks in the system exactly. This is obtained by modifying the feedback controller through the YJBK transfer function together with pre- and post-filters. The estimation is then derived using standard methods.

General information
State: Published
Organisations: Automation, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Niemann, H. H., Poulsen, N. K.
Pages: 5186-5191
Publication date: 2008

Host publication information
Title of host publication: Estimation of Model Uncertainties in Closed-loop Systems
Place of publication: Washington
Publisher: American Control Conference
ISBN (Print): 978-1-4244-2078-0
Electronic versions:
Niemann.pdf
DOIs:
10.1109/ACC.2008.4587318

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Source: orbit
Source-ID: 220862
Research output: Research - peer-review » Article in proceedings – Annual report year: 2008

Improving Convergence of Iterative Feedback Tuning using Optimal External Perturbations
Iterative feedback tuning constitutes an attractive control loop tuning method for processes in the absence of sufficient process insight. It is a purely data driven approach to optimization of the loop performance. The standard formulation ensures an unbiased estimate of the loop performance cost function gradient, which is used in a search algorithm. A slow rate of convergence of the tuning method is often experienced when tuning for disturbance rejection. This is due to a poor signal to noise ratio in the process data. A method is proposed for increasing the information content in data by introducing an optimal perturbation signal in the tuning algorithm. For minimum variance control design the optimal design of an external perturbation signal is derived in terms of the asymptotic accuracy of the iterative feedback tuning method.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Computer Aided Process Engineering Center
Contributors: Huusom, J. K., Hjalmarsson, H., Poulsen, N. K., Jørgensen, S. B.
Publication date: 2008

Event information
Event: 47th IEEE Conference on Decision and Control
Location: Fiesta Americana Grand Coral Beach, Cancun, Mexico
Source: orbit
Source-ID: 231409
Research output: Research » Sound/Visual production (digital) – Annual report year: 2008

Improving Convergence of Iterative Feedback Tuning using Optimal External Perturbations
Iterative feedback tuning constitutes an attractive control loop tuning method for processes in the absence of sufficient process insight. It is a purely data driven approach to optimization of the loop performance. The standard formulation ensures an unbiased estimate of the loop performance cost function gradient, which is used in a search algorithm. A slow rate of convergence of the tuning method is often experienced when tuning for disturbance rejection. This is due to a poor signal to noise ratio in the process data. A method is proposed for increasing the information content in data by introducing an optimal perturbation signal in the tuning algorithm. For minimum variance control design the optimal design of an external perturbation signal is derived in terms of the asymptotic accuracy of the iterative feedback tuning method.

General information
State: Published
Organisations: Computer Aided Process Engineering Center, Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Individual pitch control of wind turbines using local inflow measurements

This paper describes a model based control approach for individually adjusting the pitch of wind turbine blades and thereby attenuating the effect of asymmetric wind loads. It is assumed that measurements of local inflow along each blade are available. This effectively provides an estimate of the load distribution along the blades. The load estimates are used in a predictive setup where inflow measured by one blade is used as basis for calculating future loads for the other blades. Simulations with a full stochastic wind field illustrate the effectiveness of the individual pitch controller as compared to controlling the pitch collectively.

Information Based Fault Diagnosis

Fault detection and isolation, (FDI) of parametric faults in dynamic systems will be considered in this paper. An active fault diagnosis (AFD) approach is applied. The fault diagnosis will be investigated with respect to different information levels from the external inputs to the systems. These inputs are disturbance inputs, reference inputs and auxiliary inputs. The diagnosis of the system is derived by an evaluation of the signature from the inputs in the residual outputs. The changes of the signatures form the external inputs are used for detection and isolation of the parametric faults.

Kalmtool Used for Mobile Robot Navigation

General information
State: Published
Organisations: Automation, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Niemann, H. H., Poulsen, N. K.
Pages: 8890-8895
Publication date: 2008

Host publication information
Title of host publication: Proceedings of the 17th IFAC World Congress
Keywords: Active fault diagnosis
Source: orbit
Source-ID: 222416
Research output: Research - peer-review › Article in proceedings – Annual report year: 2008
Modelling the nonlinear temperature response of district heating systems for model predictive control applications

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Publication date: 2008

MPC for uncertain systems using the Youla parameterizations
Several approaches have been taken in the past to deal with uncertainty in constrained predictive control. The major drawbacks of these efforts are usually either conservativeness and/or on-line computational complexity. In this work we examine the possibility of dealing with uncertainty through the use of the primary and the dual Youla parameterizations. The dual Youla parameter can be seen as a frequency weighted measure of the uncertainty and the primary Youla parameter can be seen as a controller for this uncertainty. The work is an application of the methodology in [12] to constraint control.

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling, Automation, Department of Electrical Engineering
Contributors: Thomsen, S. C., Niemann, H. H., Poulsen, N. K.
Pages: 3421-3426
Publication date: 2008

Oestrus Detection in Dairy Cows Using Likelihood Ratio Tests
This paper addresses detection of oestrus in dairy cows using methods from statistical change detection. The activity of the cows was measured by a necklace attached sensor. Statistical properties of the activity measure were investigated. Using data sets from 17 cows, diurnal activity variations were identified for the ensemble and for the individual cows. A
diurnal filter was adapted to remove the daily variation of the individual. Change detection algorithms were designed for the actual probability densities, which were Rayleigh distributed with individual parameters for each cow. A generalized likelihood ratio algorithm was derived for the compensated activity signal and detection algorithm was tested on 2323 days of activity, which contained 42 oestruses on 12 cows in total. The application of statistical change detection methods is a new approach for detecting oestrus in dairy cows and the results are shown to outperform earlier approaches in respect to combined statistics of false alarms and missed detections.
A fatigue approach to wind turbine control

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Hammerum, K., Brath, P., Poulsen, N. K.
Publication date: 2007

Host publication information
Title of host publication: TWIND2007, 28-31 august DTU
Publisher: Technical University of Denmark (DTU)
URLs:
http://www2.imm.dtu.dk/pubdb/views/publication_details.php?id=5277
Source: orbit
Source-ID: 202538
Research output: Research › peer-review › Article in proceedings – Annual report year: 2007

A Generalized Autocovariance Least-Squares Method for Covariance Estimation

A generalization of the autocovariance least-squares method for estimating noise covariances is presented. The method can estimate mutually correlated system and sensor noise and can be used with both the predicting and the filtering form of the Kalman filter.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Scientific Computing, Department of Informatics and Mathematical Modeling, Mathematical Statistics, Computer Aided Process Engineering Center
Contributors: Åkesson, B. M., Jørgensen, J. B., Poulsen, N. K., Jørgensen, S. B.
Publication date: 2007

Host publication information
Title of host publication: American Control Conference 2007
Publisher: IEEE
ISBN (Print): 1-4244-0988-8
Electronic versions:
Åkeson.pdf
DOIs:
10.1109/ACC.2007.4282878
A Multi-Model Approach for System Diagnosis
A multi-model approach for system diagnosis is presented in this paper. The relation with fault diagnosis as well as performance validation is considered. The approach is based on testing a number of pre-described models and find which one is the best. It is based on an active approach, i.e. an auxiliary input to the system is applied. The multi-model approach is applied on a wind turbine system.

General information
State: Published
Organisations: Automation, Department of Electrical Engineering, Department of Informatics and Mathematical Modeling
Contributors: Niemann, H. H., Poulsen, N. K., Bækgaard, M. A. B.
Pages: 2539-2544
Publication date: 2007

A Novel Algorithm for Enhanced Convergence of the Iterative Feedback Tuning Method

General information
State: Published
Organisations: Computer Aided Process Engineering Center, Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B.
Publication date: 2007

A Tool for Kalman Filter Tuning

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Scientific Computing, Department of Informatics and Mathematical Modeling, Mathematical Statistics, Computer Aided Process Engineering Center
Contributors: Åkesson, B. M., Jørgensen, J. B., Poulsen, N. K., Jørgensen, S. B.
Publication date: 2007
A Tool for Kalman Filter Tuning
The Kalman filter requires knowledge about the noise statistics. In practical applications, however, the noise covariances are generally not known. A method for estimating noise covariances from process data has been investigated. The method gives a least-squares estimate of the noise covariances, which can be used to compute the Kalman filter gain.

Data Driven Controller Tuning

Data Driven Controller Tuning
Data Driven Controller Tuning

General information
State: Published
Organisations: Computer Aided Process Engineering Center, Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B.
Publication date: 2007

Event information
Event: KTH, Stockholm
Location: Sweden, 27 September
Source: orbit
Source-ID: 208072
Research output: Research › Sound/Visual production (digital) – Annual report year: 2007

Data Driven Tuning of Inventory Controllers

A systematic method for criterion based tuning of inventory controllers based on data-driven iterative feedback tuning is presented. This tuning method circumvent problems with modeling bias. The process model used for the design of the inventory control is utilized in the tuning as an approximation to reduce time required on experiments. The method is illustrated in an application with a multivariable inventory control implementation on a four tank system.

General information
State: Published
Organisations: Computer Aided Process Engineering Center, Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Huusom, J. K., Santacoloma, P. A., Poulsen, N. K., Jørgensen, S. B.
Pages: 4191-4196
Publication date: 2007

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Title of host publication: 46th IEEE Conference on Decision and Control
Publisher: IEEE
ISBN (Print): 978-1-4244-1497-0
Electronic versions: Huusom.pdf
DOIs: 10.1109/CDC.2007.4434207

Bibliographical note
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Data Driven Tuning of Lower Level Controllers for Disturbance Rejections

General information
State: Published
Organisations: Computer Aided Process Engineering Center, Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B.
Publication date: 2007

Event information
Event: European Congress of Chemical Engineering - 6
Location: Copenhagen, Denmark
Source: orbit
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Research output: Research › Sound/Visual production (digital) – Annual report year: 2007

Estimation of noise covariances and identification of disturbance structure using the autocovariance least-squares method

General information
State: Published
Organisations: Computer Aided Process Engineering Center, Department of Chemical and Biochemical Engineering, Scientific Computing, Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Åkesson, B. M., Jørgensen, J. B., Poulsen, N. K., Jørgensen, S. B.
Pages: 553-554
Publication date: 2007

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Source-ID: 207012
Research output: Research › Article in proceedings – Annual report year: 2007

Estimation of noise covariances and identification of disturbance structure using the autocovariance least-squares method

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Scientific Computing, Department of Informatics and Mathematical Modeling, Mathematical Statistics, Computer Aided Process Engineering Center
Contributors: Åkesson, B. M., Jørgensen, J. B., Poulsen, N. K., Jørgensen, S. B.
Publication date: 2007

Event information
Event: European Congress of Chemical Engineering - 6
Location: Copenhagen, Denmark
Source: orbit
Source-ID: 208063
Research output: Research › Sound/Visual production (digital) – Annual report year: 2007

Improving Model Predictive Control Performance Using Disturbance Estimation

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Scientific Computing, Department of Informatics and Mathematical Modeling, Mathematical Statistics, Computer Aided Process Engineering Center
Contributors: Åkesson, B. M., Jørgensen, J. B., Poulsen, N. K., Jørgensen, S. B.
Publication date: 2007
Improving Model Predictive Control Performance using Disturbance Estimation and Systematic Kalman Filter Tuning

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Scientific Computing, Department of Informatics and Mathematical Modeling, Mathematical Statistics, Computer Aided Process Engineering Center
Contributors: Åkesson, B. M., Jørgensen, J. B., Poulsen, N. K., Jørgensen, S. B.
Publication date: 2007
Peer-reviewed: Yes
Source: orbit
Source-ID: 224380
Research output: Research - peer-review › Conference abstract for conference – Annual report year: 2007

Iterative Controller Tuning for Processes with Fold Bifurcations

General information
State: Published
Organisations: Computer Aided Process Engineering Center, Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B.
Publication date: 2007

Event information
Event: 17th European Symposium on Computer Aided Process Engineering
Location: Bucharest, Romania
Source: orbit
Source-ID: 208054
Research output: Research › Sound/Visual production (digital) – Annual report year: 2007

Iterative Controller Tuning for Process with Fold Bifurcations
Processes involving fold bifurcation are notoriously difficult to control in the vicinity of the fold where most often optimal productivity is achieved. In cases with limited process insight a model based control synthesis is not possible. This paper uses a data driven approach with an improved version of iterative feedback tuning to optimizing a closed loop performance criterion, as a systematic tool for tuning process with fold bifurcations.

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Computer Aided Process Engineering Center
Model Predictive Control with Constraints of a Wind Turbine

Model predictive control of wind turbines offer a more systematic approach of constructing controllers that handle constraints while focusing on the main control objective. In this article several controllers are designed for different wind conditions and appropriate switching conditions ensure an efficient control of the wind turbine over the entire range of wind speeds. Both onshore and floating offshore wind turbines are tested with the controllers.

Stochastic Change Detection based on an Active Fault Diagnosis Approach

The focus in this paper is on stochastic change detection applied in connection with active fault diagnosis (AFD). An auxiliary input signal is applied in AFD. This signal injection in the system will in general allow to obtain a fast change detection/isolation by considering the output or an error output from the system. The classical CUSUM (cumulative sum) method will be modified such that it will be able to detect change in the signature from the auxiliary input signal in the (error) output signal. It will be shown how it is possible to apply both the gain as well as the phase change of the output vector in the CUSUM test.
Temperature prediction in district heating systems with cFIR models

Using Kalmtool in Navigation of Mobile Robots

A Generalized Autocovariance Least-Squares Method for Kalman Filter Tuning
Analysis and Design Environment for Flexible Manipulators

General information
State: Published
Organisations: Automation, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Ravn, O., Poulsen, N. K.
Publication date: 2006

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Publisher: Peter Peregrinus Ltd
ISBN (Print): 978-0863414480
Electronic versions:
imm3150.ps
imm3150.pdf
Source: orbit
Source-ID: 200661
Research output: Research - peer-review › Book chapter – Annual report year: 2006

A Simulation Platform for Localization and Mapping

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling, Department of Electrical Engineering
Contributors: Sejereøe, T. H., Poulsen, N. K., Ravn, O.
Pages: 937-942
Publication date: 2006

Host publication information
Title of host publication: IFAC SYSID 2006 in Newcastle, Australia
Electronic versions:
imm3946.pdf
URLs:
http://www2.imm.dtu.dk/pubdb/p.php?3946
Source: orbit
Source-ID: 191570
Research output: Research - peer-review › Article in proceedings – Annual report year: 2006

Closed loop identification for Nonlinear process models. Challenges and Methods.

General information
State: Published
Organisations: Computer Aided Process Engineering Center, Department of Chemical and Biochemical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Huusom, J. K., Poulsen, N. K., Jørgensen, S. B.
Publication date: 2006

Host publication information
Title of host publication: Proceedings of the 14th Symposium on System Identification
Source: orbit
Source-ID: 199918
Research output: Research › Article in proceedings – Annual report year: 2006
Fault tolerant control for uncertain systems with parametric faults
A fault tolerant control (FTC) architecture based on active fault diagnosis (AFD) and the YJBK (Youla, Jarb, Bongiorno and
Kucera)parameterization is applied in this paper. Based on the FTC architecture, fault tolerant control of uncertain systems
with slowly varying parametric faults is investigated. Conditions are given for closed-loop stability in case of false alarms or
missing fault detection/isolation.

General information
State: Published
Organisations: Automation, Department of Electrical Engineering, Department of Informatics and Mathematical Modeling
Contributors: Niemann, H. H., Poulsen, N. K.
Pages: 517-322
Publication date: 2006

Host publication information
Title of host publication: Proceedings of the 6th IFAC Symposium on Fault Detection Supervision ans Safety for Technical
Processes
Keywords: Fault tolerant control, active fault diagnosis, dynamic systems, feedback control, controller reconfiguration,
uncertain systems
URLs:
Source: orbit
Source-ID: 194275
Research output: Research - peer-review › Article in proceedings – Annual report year: 2006

Model Identification for Control

General information
State: Published
Organisations: Computer Aided Process Engineering Center, Department of Chemical and Biochemical Engineering,
Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Huusom, J. K., Jørgensen, S. B., Poulsen, N. K.
Pages: 172-173
Publication date: 2006

Host publication information
Title of host publication: Dansk Kemiingeniørkonference – DK2-2006
Publisher: DK2
Source: orbit
Source-ID: 191270
Research output: Research › Article in proceedings – Annual report year: 2006

Rapprochement between Active Fault Diagnosis and Change Detection in ARMAX Systems
The connection between AFD (Active Fault Diagnosis), ARMAX systems and RST controllers etc. are considered in this
paper. It is shown that the applied setup in modern AFD for closed loop systems can be considered as a generalization of
the setup used in connection with traditional methods for system identification and controller design in the polynomial
setting.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Automation, Department of Electrical Engineering
Contributors: Poulsen, N. K., Niemann, H. H.
Pages: 493-498
Publication date: 2006

Host publication information
Title of host publication: Preprints of the 14th IFAC Symposium on System Identiﬁcation, SYSID 2006
Volume: 1
Publisher: International Federation of Automatic Control
URLs:
Source: orbit
Source-ID: 189153
Research output: Research - peer-review › Article in proceedings – Annual report year: 2006
Active fault diagnosis in closed-loop systems
Active fault diagnosis (AFD) of parametric faults is considered in connection with closed loop feedback systems. AFD involves auxiliary signals applied on the closed loop system. A fault signature matrix is introduced in connection with AFD and it is shown that if a limited number of faults can occur in the system, a fault separation in the fault signature matrix can be obtained. Then the single elements in the matrix only depend of a reduced number of parametric faults. This can directly be applied for fault isolation. If it is not possible to obtain this separation, it is shown how the fault signature matrix can be applied for a dynamical fault isolation, i.e. fault isolation based on the dynamic characteristic of the fault signature matrix as function of the different parametric faults.

General information
State: Published
Organisations: Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Niemann, H. H., Poulsen, N. K.
Publication date: 2005

Host publication information
Title of host publication: IFAC World Congress
Keywords: Fault diagnosis, feedback control, dynamic systems, parametric faults
Source: orbit
Source-ID: 182404
Research output: Research - peer-review › Article in proceedings – Annual report year: 2005

A new evaluation platform for Navigation systems

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling, Automation, Department of Electrical Engineering
Contributors: Sejerøe, T. H., Poulsen, N. K., Ravn, O.
Publication date: 2005

Host publication information
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Publisher: Elsevier
ISBN (Print): 0-08-045108-X
Electronic versions:
imm3342.pdf
URLs:
http://www2.imm.dtu.dk/pubdb/p.php?3342
Source: orbit
Source-ID: 185745
Research output: Research - peer-review › Article in proceedings – Annual report year: 2005

Comparison between a PI and LQ-regulation for a 2 MW wind turbine

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling, Risø National Laboratory for Sustainable Energy, Wind Energy Division, Aeroelastic Design
Contributors: Poulsen, N. K., Larsen, T. J., Hansen, M. H.
Publication date: 2005

Publication information
Original language: English
Electronic versions:
imm3619.pdf
URLs:
http://www2.imm.dtu.dk/pubdb/p.php?3619
Source: orbit
Source-ID: 185955
Research output: Research - peer-review › Report – Annual report year: 2005
Pay-load Estimation of a 2 DOF Flexible Link Robot
The paper presents a new method for online identification of pay-loads for a two-link flexible robot. The method benefits from the close correspondence between parameters of a discrete-time model represented by means of the Delta-Operator, and those of the underlying continuous-time model. Although the applied principle might be general in nature, the paper is applied to the well-known problem of identifying a pay-load of a moving flexible robot. This problem is almost impossible to solve by measurements, so an estimation technique must be applied. The presented method benefits from the close correspondence with the continuous-time representation to allow a scalar and implicit adaptive technique which based on flexibility measurements leads to the online estimation of the pay-load.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics, Department of Electrical Engineering, Automation and Control
Contributors: Poulsen, N. K., Ravn, O.
Publication date: 2005

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Keywords: Parameter Estimation, Adaptive Control, System Identification, Flexible Link Robot, Delta-Operator
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Research output: Research - peer-review › Article in proceedings – Annual report year: 2005

Pay-Load Estimation of a 2DOF Flexible Link Robot

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling, Automation, Department of Electrical Engineering
Contributors: Poulsen, N. K., Ravn, O.
Publication date: 2005

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Title of host publication: CLAWAR
Electronic versions: imm3899.pdf
Source: orbit
Source-ID: 200342
Research output: Research - peer-review › Article in proceedings – Annual report year: 2005

Process identification Challenges for Nonlinear Model Predictive Control

General information
State: Published
Organisations: Department of Chemical and Biochemical Engineering, Department of Informatics and Mathematical Modeling
Contributors: Huusom, J. K., Bonne, D., Poulsen, N. K., Jørgensen, S. B.
Pages: 451-458
Publication date: 2005

Host publication information
Title of host publication: International Workshop on Assesment and Future Directions of Nonlinear Model Predictive Control, Freudenstadt-Lauterbad, Germ
URLs: http://www2.imm.dtu.dk/pubdb/p.php?3958
Source: orbit
Source-ID: 182383
Research output: Research - peer-review › Article in proceedings – Annual report year: 2005

Simultanuous Location and Mapping - A Simulation Platform

General information
Stochastic Control - External Models

This note is devoted to control of stochastic systems described in discrete time. We are concerned with external descriptions or transfer function model, where we have a dynamic model for the input output relation only (i.e., no direct internal information). The methods are based on LTI systems and quadratic costs. We will start with the basic minimal variance problem and then move on to more complex and applicable strategies such as GMV, GPC and LQG control. These methods can be regarded as extension to the basic minimal variance strategy and have all a close relation to prediction. Consequently a section on that topic can be found in appendix.

Wind farm controllers with grid support

Dynamic Optimization
Pressetørring af parketstave. Fysisk model

General information
State: Published
Organisations: Department of Mathematics, Department of Informatics and Mathematical Modeling, F. Junckers Industrier A/S, Danish Technological Institute
Contributors: Sørensen, M. P., Poulsen, N. K., Jensen, S. K., Pinholt, P., Morsing, N.
Number of pages: 31
Publication date: 2004

Publication information
Place of publication: Kongens Lyngby
Publisher: Informatics and Mathematical Modelling, Technical University of Denmark, DTU
Edition: 15
Original language: Danish
(IMM teknisk rapport; No. 2004-15).
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Source-ID: 61808
Research output: Research › Report – Annual report year: 2004

Pressetørring af parketstave - Simulationsmodel

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling, Department of Civil Engineering
Contributors: Poulsen, N. K., Sørensen, M. P., Pinholt, P., Jensen, S. K., Morsing, N.
Publication date: 2004

Publication information
Original language: English
Electronic versions:
imm3291.pdf
imm3291.ps
URLs:
Source: orbit
Source-ID: 154861
Research output: Research › Report – Annual report year: 2004

Simulation and optimization of wind farm controller

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Sørensen, P., Hansen, A. D., Thomsen, K., Madsen, H., Nielsen, H. A., Poulsen, N. K., Iov, F., Blaabjerg, F., Okkels, B.
The Matrix exponential, Dynamic Systems and Control

The matrix exponential can be found in various connections in analysis and control of dynamic systems. In this short note we are going to list a few examples. The matrix exponential usably pops up in connection to the sampling process, whatever it is in a deterministic or a stochastic setting or it is a tool for determining a Gramian matrix. This note is intended to be used in connection to the teaching post the course in Stochastic Adaptive Control (02421) given at Informatics and Mathematical Modelling (IMM), The Technical University of Denmark. This work is a result of a study of the litterature.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems
Contributors: Poulsen, N. K.
Number of pages: 15
Publication date: 2004

Adaptation in the fuzzy self-organising controller

This simulation study provides an analysis of the adaptation mechanism in the self-organising fuzzy controller, SOC. The approach is to apply a traditional adaptive control viewpoint. A simplified performance measure in the SOC controller is used in a loss function, and thus the MIT rule implies an update mechanism similar to the SOC update mechanism. Two simulations of proportionally controlled systems show the behaviour of the proportional gain as it adapts to a specified behaviour.

General information
State: Published
Organisations: Department of Electrical Engineering, Department of Informatics and Mathematical Modeling
Contributors: Jantzen, J., Poulsen, N. K.
Pages: 49-57
Publication date: 2003

Contribution to a dynamic wind turbine model validation from a wind farm islanding experiment

Measurements from an islanding experiment on the Rejsby Hede wind farm, Denmark, are used for the validation of the dynamic model of grid-connected, stall-controlled wind turbines equipped with induction generators. The simulated results are found to be in good agreement with the measurements and possible discrepancies are explained. The work with the wind turbine model validation relates to the dynamic stability investigations on incorporation of large amount of wind power in the Danish power grid, where the dynamic wind turbine model is applied.
Iterative Identification for Control and Robust Performance of Bioreactor

General information
State: Published
Organisations: Automation, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Computer Aided Process Engineering Center, Department of Chemical and Biochemical Engineering
Contributors: Bøjstrup, K., Niemann, H. H., Poulsen, N. K., Jørgensen, S. B.
Pages: 1673-1678
Publication date: 2003

Host publication information
Title of host publication: 13th IFAC symposium on System Identification
URLs:
Source: orbit
Source-ID: 58508
Research output: Research - peer-review » Article in proceedings – Annual report year: 2003

KALMTOOL for use with MATLAB
The KALMTOOL toolbox is a set of MATLAB tools for state estimation for nonlinear systems. The toolbox contains functions for extended Kalman filtering as well as for two new filters called the DD1 filter and the DD2 filter. The toolbox specifically addresses the problem of not having observations available at all sampling instants. All functions are available as m-functions but for faster (much faster!) execution, the DD1 and DD2 filters are also available as C Mex files for MATLAB under Windows and Linux. The toolbox requires MATLAB 6. No additional toolboxes are required.

General information
State: Published
Organisations: Automation, Department of Electrical Engineering, Department of Informatics and Mathematical Modeling
Contributors: Nørgaard, P. M., Ravn, O., Poulsen, N. K.
Publication date: 2003

Host publication information
Title of host publication: 13th IFAC Symposium on System Identification SYSID03
URLs:
Source: orbit
Modelling and transient stability of large wind farms

The paper is dealing with modelling and short-term Voltage stability considerations of large wind farms. A physical model of a large offshore wind farm consisting of a large number of windmills is implemented in the dynamic simulation tool PSS/E. Each windmill in the wind farm is represented by a physical model of grid-connected windmills. The windmill generators are conventional induction generators and the wind farm is ac-connected to the power system. Improvements of short-term voltage stability in case of failure events in the external power system are treated with use of conventional generator technology. This subject is treated as a parameter study with respect to the windmill electrical and mechanical parameters and with use of control strategies within the conventional generator technology. Stability improvements on the wind farm side of the connection point lead to significant reduction of dynamic reactive compensation demands. In case of blade angle control applied at failure events, dynamic reactive compensation is not necessary for maintaining the voltage stability.

General information
State: Published
Organisations: Department of Electrical Engineering, Department of Electric Power Engineering, Department of Informatics and Mathematical Modeling
Contributors: Akhmatov, V., Knudsen, H., Nielsen, A. H., Pedersen, J. K., Poulsen, N. K.
Pages: 123-144
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Peer-reviewed: Yes

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BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 4.63 SJR 1.276 SNIP 1.662
Web of Science (2017): Impact factor 3.61
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.3 SJR 1.472 SNIP 1.843
Web of Science (2016): Impact factor 3.289
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 3.97 SJR 1.441 SNIP 2.031
Web of Science (2015): Impact factor 2.587
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 4.34 SJR 1.328 SNIP 2.312
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 4.54 SJR 1.231 SNIP 2.731
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 4.37 SJR 1.106 SNIP 2.758
Web of Science (2012): Impact factor 3.432
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Short-circuit impedance measurement

Methods for estimating the short-circuit impedance in the power grid are investigated for various voltage levels and situations. The short-circuit impedance is measured, preferably from naturally occurring load changes in the grid, and it is shown that such a measurement system faces different kinds of problems at different locations in the grid. This means that the best measurement methodology changes depending on the location in the grid. Three typical examples with different measurement problems at 400 kV, 132 kV and 400 V voltage level are discussed.

General information

State: Published
Organisations: Department of Electrical Engineering, Department of Informatics and Mathematical Modeling
Contributors: Pedersen, K. O. H., Nielsen, A. H., Poulsen, N. K.
Pages: 169-174
Publication date: 2003
Peer-reviewed: Yes

Publication information

Journal: IEE Proceedings-Generation Transmission and Distribution
Volume: 150
Issue number: 2
ISSN (Print): 1350-2360
Ratings:
BFI (2017): BFI-level 1
BFI (2016): BFI-level 1
Delta-operator techniques for pay-load estimation of a 2DOF flexible link robot

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics, Department of Electrical Engineering
Contributors: Jensen, M. R., Poulsen, N. K., Ravn, O.
Publication date: 2002

Publication information
Original language: English
URLs:
Source: orbit
Source-ID: 58395
Research output: Research - peer-review › Report – Annual report year: 2002

Grey-box modelling of aeration tank settling

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Bechmann, H., Nielsen, M. K., Poulsen, N. K., Madsen, H.
Pages: 1887-1895
Publication date: 2002
Peer-reviewed: Yes

Publication information
Journal: Water research
Volume: 36
Issue number: 7
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 7.55 SJR 2.601 SNIP 2.358
Web of Science (2017): Impact factor 7.051
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 7.49 SJR 2.663 SNIP 2.563
Web of Science (2016): Impact factor 6.942
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 6.63 SJR 2.665 SNIP 2.482
Web of Science (2015): Impact factor 5.991
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 6.13 SJR 2.946 SNIP 2.702
Web of Science (2014): Impact factor 5.528
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 6.02 SJR 2.956 SNIP 2.676
Web of Science (2013): Impact factor 5.323
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 5.15 SJR 2.914 SNIP 2.442
Web of Science (2012): Impact factor 4.655
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 5.43 SJR 2.862 SNIP 2.355
Web of Science (2011): Impact factor 4.865
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.592 SNIP 2.192
Web of Science (2010): Impact factor 4.546
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.319 SNIP 2.224
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 2.073 SNIP 2.178
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.94 SNIP 2.184
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.902 SNIP 2.233
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 2.113 SNIP 2.334
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 2.209 SNIP 2.108
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 1.702 SNIP 1.908
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 1.568 SNIP 1.757
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 1.319 SNIP 1.69
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 1.399 SNIP 1.662
NNSYSID - toolbox for system identification with neural networks

The NNSYSID toolset for System Identification has been developed as an add on to MATLAB(R). The NNSYSID toolbox has been designed to assist identification of nonlinear dynamic systems. It contains a number of nonlinear model structures based on neural networks, effective training algorithms and tools for model validation and model structure selection. This paper gives an overview of the design of NNSYSID and demonstrates its features in an example.

General information
State: Published
Organisations: Department of Electrical Engineering, Department of Informatics and Mathematical Modeling
Contributors: Norgaard, M., Ravn, O., Poulsen, N. K.
Pages: 1-20
Publication date: 2002
Peer-reviewed: Yes

Publication information
Journal: Mathematical and computer modelling of dynamical systems
Volume: 8
Issue number: 1
ISSN (Print): 1387-3954
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 0.83 SJR 0.218 SNIP 0.709
Web of Science (2017): Impact factor 0.586
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 0.65 SJR 0.249 SNIP 0.617
Web of Science (2016): Impact factor 0.439
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 0.92 SJR 0.286 SNIP 0.834
Web of Science (2015): Impact factor 0.625
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 1.19 SJR 0.418 SNIP 0.813
Web of Science (2014): Impact factor 0.492
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 0.98 SJR 0.426 SNIP 0.812
Web of Science (2013): Impact factor 0.984
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 1.08 SJR 0.358 SNIP 0.978
Web of Science (2012): Impact factor 0.833
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 0.71 SJR 0.314 SNIP 0.891
Web of Science (2011): Impact factor 0.406
Constrained Predictive Control and its application to a Coupled-tanks Apparatus

The focus of this paper is the development and application to experimental equipment of fast constrained predictive control algorithms. A review of QP based algorithm and an alternative using interpolation and LP is considered. Despite its undemanding computational nature, the latter algorithm is found to perform well both in simulation and when applied to an actual coupled-tanks rig. The advantages of the algorithm are further illustrated by comparison with desaturated PID control.

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K., Kouvaritakis, B., Cannon, M.
Pages: 552-564
Publication date: Apr 2001
Peer-reviewed: Yes

Publication information
Journal: International Journal of Control
Volume: 74
Issue number: 6
ISSN (Print): 0020-7179
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 2.51 SJR 1.152 SNIP 1.237
Web of Science (2017): Impact factor 2.101
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.55 SJR 1.218 SNIP 1.382
Web of Science (2016): Impact factor 2.208
Web of Science (2016): Indexed yes
Modelling and Transient Stability of Large Wind Farms

General information
State: Published
Organisations: Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Akhmatov, V., Knudsen, H., Nielsen, A. H., Petersen, J. K., Poulsen, N. K.
Pages: 1-14

Original language: English
DOIs:
10.1080/00207170010018788
Source: orbit
Source-ID: 57794
Research output: Research - peer-review › Journal article – Annual report year: 2001
NNSYSID and NNCTRL Tools for system identification and control with neural networks

Two toolsets for use with MATLAB have been developed: the neural network based system identification toolbox (NNSYSID) and the neural network based control system design toolkit (NNCTRL). The NNSYSID toolbox has been designed to assist identification of nonlinear dynamic systems. It contains a number of nonlinear model structures based on neural networks, effective training algorithms and tools for model validation and model structure selection. The NNCTRL toolkit is an add-on to NNSYSID and provides tools for design and simulation of control systems based on neural networks. The user can choose among several designs such as direct inverse control, internal model control, nonlinear feedforward, feedback linearisation, optimal control, gain scheduling based on instantaneous linearisation of neural network models and nonlinear model predictive control. This article gives an overview of the design of NNSYSID and NNCTRL.

Nonlinear constrained predictive control applied to a coupled-tanks apparatus

General information
Path following mobile robot in the presence of velocity constraints
This paper focuses on path following algorithms for mobile robots with velocity constraints on the wheels. The path considered consists of straight lines intersected with given angles. We present a fast real-time receding horizon controller which anticipates the intersections and smoothly controls the robot through the turnings while fulfilling the velocity constraints.

Pay-load estimation of a 2DOF flexible link robot using a delta-operator technique
The paper presents a new method for online identification of pay-loads for a two-link flexible robot. The method benefits from the close correspondence between parameters of a discrete-time model represented by means of the Delta-Operator, and those of the underlying continuous-time model. Although the applied principle might be general in nature, the paper is applied to the well-known problem of identifying a pay-load of a moving flexible robot. This problem is almost impossible to solve by measurements, so an estimation technique must be applied. The presented method benefits from the close correspondence with the continuous-time representation to allow a scalar and implicit adaptive technique which based on flexibility measurements leads to the online estimation of the pay-load.
Receding Horizon Approach to Path Following Mobile Robot in the Presence of Constraints.

General information
State: Published
Organisations: Department of Automation, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Automation, Department of Electrical Engineering
Contributors: Bak, M., Poulsen, N. K., Ravn, O.
Pages: 1151-1156
Publication date: 2001

Short-term Stability of Large-Scale Wind Farms

General information
State: Published
Organisations: Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Akhmatov, V., Knudsen, H., Nielsen, A. H., Poulsen, N. K., Petersen, J. K.
Pages: 1181-1186
Publication date: 2001

A Dynamic Stability Limit of Grid Connected Induction Generators

General information
State: Published
Organisations: Department of Electric Power Engineering, Electric Energy Systems, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Akhmatov, V., Knudsen, H., Brunnt (fratrådt), M., Nielsen, A. H., Pedersen, J. K., Poulsen, N. K.
Pages: 235-244
Publication date: 2000
Analysis of wind farm islanding experiment
This paper deals with the problems related to an islanding experiment performed at Rejsby Hede in Denmark. During the experiment several interesting observations were made in connection to distortion of voltages and currents. Observations were also made in connection to variation of frequency and phase. In this paper the data are analyzed in three different manners and the results are related to the physics of the electric system.

General information
State: Published
Organisations: Department of Electric Power Engineering, Electric Power Engineering, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling, Sydkraft AB
Contributors: Pedersen, J. K., Pedersen, K. O. H., Poulsen, N. K., Akke, M.
Pages: 110-115
Publication date: 2000
Peer-reviewed: Yes

Publication information
Journal: IEEE Transactions on Energy Conversion
Volume: 15
Issue number: 01
ISSN (Print): 0885-8969
Ratings:
BFI (2019): BFI-level 2
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Scopus rating (2017): CiteScore 5.42 SJR 1.377 SNIP 2.124
Web of Science (2017): Impact factor 3.767
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 5.08 SJR 1.356 SNIP 2.25
Web of Science (2016): Impact factor 3.808
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 5.22 SJR 1.454 SNIP 2.631
Web of Science (2015): Impact factor 2.596
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 5.03 SJR 1.471 SNIP 2.817
Web of Science (2014): Impact factor 2.326
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 5.67 SJR 1.798 SNIP 3.21
Web of Science (2013): Impact factor 3.353
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 5.48 SJR 1.565 SNIP 3.154
Web of Science (2012): Impact factor 2.427
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 5.35 SJR 1.568 SNIP 2.995
Web of Science (2011): Impact factor 2.272
Grey Box Modelling of First Flush and Incoming Wastewater at a Wastewater Treatment Plant

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Bechmann, H., Madsen, H., Poulsen, N. K., Nielsen, M. K.
Pages: 1-12
Publication date: 2000
Peer-reviewed: No

Publication information
Journal: Environmetrics
Volume: 11
ISSN (Print): 1180-4009
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 1.36 SJR 1.014 SNIP 0.875
Web of Science (2017): Impact factor 1.321
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.59 SJR 0.989 SNIP 1.029
Web of Science (2016): Impact factor 1.532
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 1.48 SJR 0.979 SNIP 0.852
Web of Science (2015): Impact factor 1.16
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 1.64 SJR 1.056 SNIP 1.153
Web of Science (2014): Impact factor 1.514
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 1.65 SJR 1.067 SNIP 1.216
Web of Science (2013): Impact factor 1.486
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 1.12 SJR 0.571 SNIP 0.921
Web of Science (2012): Impact factor 1.096
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 1.3 SJR 0.54 SNIP 0.994
Web of Science (2011): Impact factor 1.06
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.681 SNIP 0.811
Web of Science (2010): Impact factor 0.75
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.563 SNIP 0.929
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.615 SNIP 0.877
Scopus rating (2007): SJR 0.578 SNIP 0.832
Scopus rating (2006): SJR 0.559 SNIP 0.81
Scopus rating (2005): SJR 0.421 SNIP 0.728
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.492 SNIP 0.703
Scopus rating (2003): SJR 0.399 SNIP 0.747
Scopus rating (2002): SJR 0.489 SNIP 0.885
Scopus rating (2001): SJR 0.369 SNIP 0.376
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 0.543 SNIP 0.839
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 0.597 SNIP 0.847
Original language: English
URLs:
Source: orbit
Source-ID: 199898
Research output: Research › Journal article – Annual report year: 2000

Neural Networks for Modelling and Control of Dynamic Systems - A Practitioner's Handbook
New developments in state estimation for Nonlinear Systems

Based on an interpolation formula, accurate state estimators for nonlinear systems can be derived. The estimators do not require derivative information which makes them simple to implement. State estimators for nonlinear systems are derived based on polynomial approximations obtained with a multi-dimensional interpolation formula. It is shown that under certain assumptions the estimators perform better than estimators based on Taylor approximations. Nevertheless, the implementation is significantly simpler as no derivatives are required. Thus, it is believed that the new state estimators can replace well-known estimators, such as the extended Kalman filter (EKF) and its higher-order relatives, in most practical applications.
Constrained Predictive Control and its application to a Coupled-tanks Apparatus

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K., Kouvaritakis, B., Cannon, M.
Publication date: 1999

Publication information
Publisher: Dept. of Engineering Science, University of Oxford, UK
Original language: English
Source: orbit
Source-ID: 201022
Research output: Research - peer-review › Report – Annual report year: 1999

Easy and Accurate State Estimation for Nonlinear Systems

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling, Automation, Department of Electrical Engineering
Contributors: Nørgaard, M., Poulsen, N. K., Ravn, O.
Pages: 343-348
Publication date: 1999
Grey-box Modelling of Pollutant Loads From a Sewer System

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Kryger
Contributors: Bechmann, H., Nielsen, M. K., Madsen, H., Poulsen, N. K.
Pages: 71-78
Publication date: 1999
Peer-reviewed: Yes

Publication information
Journal: Urban Water
Volume: 1
Ratings:
Scopus rating (2005): SJR 1.171 SNIP 3.258
Scopus rating (2004): SJR 0.552 SNIP 1.54
Scopus rating (2003): SJR 0.595 SNIP 1.775
Scopus rating (2002): SJR 0.673 SNIP 0.835
Scopus rating (2001): SJR 0.254 SNIP 0.537
Scopus rating (2000): SJR 0.178 SNIP 0.105
Original language: English
Source: orbit
Source-ID: 173062
Research output: Research - peer-review > Journal article – Annual report year: 1999

Implementation of neural network based non-linear predictive control

General information
State: Published
Organisations: Department of Automation, Department of Informatics and Mathematical Modeling
Contributors: Sørensen, P. H., Nørgård, P. M., Ravn, O., Poulsen, N. K.
Pages: 37-51
Publication date: 1999
Peer-reviewed: Yes

Publication information
Journal: Journal of Neurocomputing
Volume: 28
Issue number: 1-3
Original language: English
Source: orbit
Source-ID: 172321
Research output: Research - peer-review > Journal article – Annual report year: 1999

Nonlinear Constrained Predictive Control and its application to a Coupled-tanks Apparatus

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K., Kouvaritakis, B., Cannon, M.
Publication date: 1999

Publication information
Publisher: Dept. of Engineering Science, University of Oxford, UK
Original language: English
Source: orbit
Source-ID: 201023
Advances in Derivative-Free State Estimation for Nonlinear Systems
In this paper we show that it involves considerable advantages to use polynomial approximations obtained with an interpolation formula for derivation of state estimators for nonlinear systems. The estimators become more accurate than estimators based on Taylor approximations, and yet the implementation is significantly simpler as no derivatives are required. Thus, it is believed that estimators derived in this way can replace well-known filters, such as the extended Kalman filter (EKF) and its higher order relatives, in most practical applications. In addition to proposing a new set of state estimators the paper also unifies recent developments in derivative-free state estimation.

A Note on the C-implementation of a New Procedure for Guide Mark based Pose Estimation

Control of Sewer systems and Wastewater treatment plants using pollutant concentration profiles
On-line measurements of pollutants in the wastewater combined with grey-box modelling are used to estimate the amount of deposits in the sewer system. The pollutant mass flow at the wastewater treatment plant is found to consist of a diurnal profile minus the deposited amount of pollutants. The diurnal profile is found to be a second order harmonic function and the pollutants deposited in the sewer are identified using first order ordinary differential equations.
Grey-Box Modelling of pollutant Loads from the Sewer System for Control of Equalisation Basins

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Bechmann, H., Nielsen, M., Madsen, H., Poulsen, N. K.
Pages: 773-780
Publication date: 1998

Host publication information
Title of host publication: the Fourth International Conference on Developments in Urban Drainage Modelling (UDM'98), London, UK
Source: orbit
Source-ID: 199966
Research output: Research - peer-review › Article in proceedings – Annual report year: 1998

Implementation of neural network based non-linear predictive
The paper describes a control method for non-linear systems based on generalized predictive control. Generalized predictive control (GPC) was developed to control linear systems including open loop unstable and non-minimum phase systems, but has also been proposed extended for the control of non-linear systems. GPC is model-based and in this paper we propose the use of a neural network for the modeling of the system. Based on the neural network model a controller with extended control horizon is developed and the implementation issues are discussed, with particular emphasis on an efficient Quasi-Newton optimization algorithm. The performance is demonstrated on a pneumatic servo system.

General information
State: Published
Organisations: Department of Automation, Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Sørensen, P. H., Nørgård, P. M., Ravn, O., Poulsen, N. K.
Pages: 69-78
Publication date: 1998

Host publication information
Incorporation of Time Delayed Measurements in a Discrete-time Kalman Filter

In many practical systems there is a delay in some of the sensor devices, for instance vision measurements that may have a long processing time. How to fuse these measurements in a Kalman filter is not a trivial problem if the computational delay is critical. Depending on how much time there is at hand, the designer has to make trade offs between optimality and computational burden of the filter. In this paper various methods in the literature along with a new method proposed by the authors will be presented and compared. The new method is based on "extrapolating" the measurement to present time using past and present estimates of the Kalman filter and calculating an optimal gain for this extrapolated measurement.

Location Estimation using Delayed Measurements

When combining data from various sensors it is vital to acknowledge possible measurement delays. Furthermore, the sensor fusion algorithm, often a Kalman filter, should be modified in order to handle the delay. The paper examines different possibilities for handling delays and applies a new technique to a sensor fusion system for estimating the location of an autonomous guided vehicle. The system fuses encoder and vision measurements in an extended Kalman filter. Results from experiments in a real environment are reported.
Neural Generalized Predictive Control of a non-linear Process

The use of neural network in non-linear control is made difficult by the fact that the stability and robustness is not guaranteed and that the implementation in real time is non-trivial. In this paper we introduce a predictive controller based on a neural network model which has promising stability qualities. The controller is a non-linear version of the well-known generalized predictive controller developed in linear control theory. It involves minimization of a cost function which in the present case has to be done numerically. Therefore, we develop the numerical algorithms necessary in substantial detail and discuss the implementation difficulties. The neural generalized predictive controller is tested on a pneumatic servo system.

Adaptive Extremum Control and Wind Turbine Control

This thesis is divided into two parts, i.e., adaptive extremum control and modelling and control of a wind turbine. The first part of the thesis deals with the design of adaptive extremum controllers for some processes which have the behaviour that process should have as high efficiency as possible. Firstly, it is assumed that the nonlinear processes can be divided into a dynamic linear part and static nonlinear part. Consequently the processes with input nonlinearity and output nonlinearity are treated separately. With the nonlinearity at the input it is easy to set up a model which is linear in parameters, and thus directly lends itself to parameter estimation and adaptive control. The extremum control law is derived based on static optimization of a performance function. For a process with nonlinearity at output the intermediate signal between the linear part and nonlinear part plays an important role. If it can be emphasized on control design. The models have been validated by experimental data obtained from an existing wind turbine. The effective wind speed experienced by the rotor of a wind turbine, which is often required by some control methods, is estimated by using a wind turbine as a wind measuring device. The investigation of control design is divided into below rated operation and above rated operation. Below rated power, the aim of control is to extract maximum energy from the wind. The pitch angle of the rotor blades is fixed at its optimal value and turbine speed is adjusted to follow the changes in wind speed. Above rated power, the control design problem is to limit and smooth the output electrical power. The pitch control is investigated for both constant speed and variable speed wind turbines. The minimization of the turbine transient loads is focussed in both cases.
Autonomous Guided Vehicle - Modelling

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling, Automation, Department of Electrical Engineering
Contributors: Nørgaard, M., Poulsen, N. K., Ravn, O.
Number of pages: 21
Publication date: 1997

Publication information
Publisher: Department of Mathematical Modelling, Technical University of Denmark
Original language: English
Source: orbit
Source-ID: 201010
Research output: Research - peer-review › Report – Annual report year: 1997

Autonomous Guided Vehicle - Sensor analysis

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling, Automation, Department of Electrical Engineering
Contributors: Nørgaard, M., Poulsen, N. K., Ravn, O.
Number of pages: 41
Publication date: 1997

Publication information
Publisher: Department of Mathematical Modelling, Technical University of Denmark
Original language: English
Source: orbit
Source-ID: 201011
Research output: Research - peer-review › Report – Annual report year: 1997

Estimating the short-circuit impedance
A method for establishing a complex value of the short-circuit impedance from naturally occurring variations in voltage and current is discussed. It is the symmetrical three phase impedance at the fundamental grid frequency there is looked for. The positive sequence components in voltage and current are derived each period, and the short-circuit impedance is estimated from variations in these components created by load changes in the grid. Due to the noisy and dynamic grid with high harmonic distortion it is necessary to threat the calculated values statistical. This is done recursively through a RLS-algorithm. The algorithms have been tested and implemented on a PC at a 132 kV substation supplying a rolling mill. Knowing the short-circuit impedance gives the rolling mill an opportunity to adjust the arc furnace operation to keep flicker below a certain level. Therefore, the PC performs a simultaneously measurement of impedance and flicker.

General information
State: Published
Organisations: Electric Power Engineering, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Nielsen, A. H., Pedersen, K. O. H., Poulsen, N. K.
Pages: 453-457
Publication date: 1997

Host publication information
Title of host publication: 32'nd Universities Power Engineering Conference, UPEC'97
Place of publication: Manchester
Publisher: UMIST
Source: orbit
Source-ID: 167798
Research output: Research - peer-review › Article in proceedings – Annual report year: 1997

Estimation of Wind Speed in connection to Wind Turbine
Extremum tracking control of a Wind turbine

GPC Using a Delta-Domain Emulator-Based Approach

This paper describes new approaches to generalized predictive control formulated in the delta (delta) domain. A new delta-domain version of the continuous-time emulator-based predictor is presented. It is shown to contain the optimal discrete-time predictor based on incomplete information as a special case. Usually, a good estimate is obtained in a much longer range of samples than obtained by the optimal predictor of the same complexity. This is particularly advantageous at fast sampling rates where a 'conventional' predictor is bound to become very computationally demanding. Two controllers are considered: one having a well-defined limit as the sampling period tends to zero, the other being a close approximation to the conventional discrete-time GPC. Both algorithms are discrete in nature and well-suited for adaptive control. The fact that delta-domain models are used does not introduce an approximation since such models can be obtained by exact sampling of continuous-time models.
Min-max control of non-linear systems with multi-dissipative opponents

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Min-max control of non-linear systems with multi-dissipative opponents

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Thygesen, U. H., Poulsen, N. K.
Publication date: 1997

Publication information
Publisher: Department of Mathematical Modelling, Technical University of Denmark
Original language: English
Source: orbit
Source-ID: 201047
Research output: Research - peer-review › Report – Annual report year: 1997

NNSYSID and NNCTRL - Matlab Tools for System Identification and Control with Neural Networks

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics, Automation and Control, Department of Electrical Engineering
Contributors: Nørgård, P. M., Poulsen, N. K., Ravn, O.
Pages: 975-981
Publication date: 1997

Host publication information
Title of host publication: 11th IFAC Symposium on System Identification (SYSID ’97)
Volume: 2
Place of publication: Fukuoka, Japan
Source: orbit
Source-ID: 168345
Research output: Research - peer-review › Article in proceedings – Annual report year: 1997

On Multi-dissipative perturbations in linear systems

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Thygesen, U. H., Poulsen, N. K.
Number of pages: 24
Publication date: 1997

Publication information
Publisher: Department of Mathematical Modelling, Technical University of Denmark
Original language: English
Source: orbit
Source-ID: 201048
Research output: Research - peer-review › Report – Annual report year: 1997

Robustness of Linear Systems towards Multi-Dissipative Perturbations
We consider the question of robust stability of a linear time invariant plant subject to dynamic perturbations, which are dissipative in the sense of Willems with respect to several quadratic supply rates. For instance, parasitic dynamics are often both small gain and passive. We reduce several robustness analysis questions to linear matrix inequalities: robust stability, robust H2 performance and robust performance in presence of disturbances with finite signal-to-noise ratios
Simultaneous H control of a finite number of plants.

**General information**
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Contributors: Thygesen, U. H., Poulsen, N. K.
Number of pages: 24
Publication date: 1997

**Publication information**
Original language: English
Source: orbit
Source-ID: 168354
Research output: Research - peer-review › Report – Annual report year: 1997

Simultaneous output Feedback H-Control of p Plants using switching

**General information**
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Contributors: Thygesen, U. H., Poulsen, N. K.
Publication date: 1997

**Host publication information**
Title of host publication: European Control Conference, Brussels, Belgium
Source: orbit
Source-ID: 200408
Research output: Research - peer-review › Article in proceedings – Annual report year: 1997

Stochastic adaptive control: Appendix Volume 5

**General information**
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K.
Number of pages: 66
Publication date: 1997

**Publication information**
Original language: Danish
Stochastic adaptive control: Basics Volume 1

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K.
Number of pages: 196
Publication date: 1997

Publication information
Original language: Danish
Source: orbit
Source-ID: 168212
Research output: Research - peer-review → Book – Annual report year: 1997

Stochastic adaptive control: Stochastic systems, filtering and control Volume 2

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K.
Number of pages: 236
Publication date: 1997

Publication information
Original language: Danish
Source: orbit
Source-ID: 168214
Research output: Research - peer-review → Book – Annual report year: 1997

Stochastic adaptive control: System identification Volume 3

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K.
Number of pages: 107
Publication date: 1997

Publication information
Original language: Danish
Source: orbit
Source-ID: 168215
Research output: Research - peer-review → Book – Annual report year: 1997

Stochastic control in the L-structure Genreg.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K., Thygesen, U. H., Lauritsen, M. B.
Publication date: 1997

Publication information
Original language: Danish
Source: orbit
Source-ID: 168194
Research output: Research - peer-review → Report – Annual report year: 1997
Stokastisk adaptiv regulering - Adaptive Systemer

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K.
Publication date: 1997

Publication information
Original language: English
URLs:
http://www2.imm.dtu.dk/pubdb/p.php?2719
Source: orbit
Source-ID: 201138
Research output: Education › Compendium/lecture notes – Annual report year: 1997

Stokastisk adaptiv regulering - Appendix

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K.
Publication date: 1997

Publication information
Original language: English
URLs:
http://www2.imm.dtu.dk/pubdb/p.php?2720
Source: orbit
Source-ID: 201139
Research output: Education › Compendium/lecture notes – Annual report year: 1997

Stokastisk adaptiv regulering - Basis

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K.
Publication date: 1997

Publication information
Original language: English
URLs:
http://www2.imm.dtu.dk/pubdb/p.php?2716
Source: orbit
Source-ID: 201135
Research output: Education › Compendium/lecture notes – Annual report year: 1997

Stokastisk adaptiv regulering - Stokastiske Systemer, filtrering og regulering

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K.
Publication date: 1997

Publication information
Original language: English
URLs:
http://www2.imm.dtu.dk/pubdb/p.php?2717
Source: orbit
Stokastisk adaptiv regulering - System identifikation

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K.
Publication date: 1997

Publication information
Original language: English
URLs:
http://www2.imm.dtu.dk/pubdb/p.php?2718
Source: orbit
Source-ID: 201137
Research output: Education › Compendium/lecture notes – Annual report year: 1997

Stokastisk Regulering i L-strukturen (Genreg)

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K., Thygesen, U. H., Lauritsen, M. B., Jensen, M. R.
Publication date: 1997

Publication information
Publisher: Department of Mathematical Modelling, Technical University of Denmark
Original language: Danish
Source: orbit
Source-ID: 201024
Research output: Research - peer-review › Report – Annual report year: 1997

Adaptive Extremum control

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Ma, X., Poulsen, N. K.
Publication date: 1996

Publication information
Publisher: Department of Mathematical Modelling, Technical University of Denmark
Original language: English
Source: orbit
Source-ID: 201095
Research output: Research - peer-review › Report – Annual report year: 1996

A state space approach to the emulator-based GPC design.
For sampled dynamical systems the delta-operator is an appealing alternative to the conventional shift operator since at rapid sampling rates it shows better numerical properties and a closer rapprochement to the continuous-time description. Thus, the structural information is easy to interpret in models and designs based on the delta-operator. The GPC controller is interesting since it is a controller that successfully has been applied to many industrial process during the last decade. The present paper discusses an emulator-based GPC, a controller design intended for fast sampled adaptive control systems where the conventional q-based techniques fail due to poor word-length characteristics.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Jensen, M. R., Lauritsen, M. B., Poulsen, N. K.
Pages: 291-301
Publication date: 1996
Intelligent Predictive Control of Nonlinear Processes Using

This paper presents a novel approach to design of generalized predictive controllers (GPC) for nonlinear processes. A neural network is used for modelling the process and a gain-scheduling type of GPC is subsequently designed. The combination of neural network models and predictive control has frequently been discussed in the neural network community. This paper proposes an approximate scheme, the approximate predictive control (APC), which facilitates the implementation and gives a substantial reduction in the required amount of computations. The method is based on a technique for extracting linear models from a nonlinear neural network and using them in designing the control system. The performance of the controller is demonstrated in a simulation study of a pneumatic servo system.

General information
State: Published
Organisations: Department of Automation, Department of Informatics and Mathematical Modeling, Mathematical Statistics, Cognitive Systems
Contributors: Nørgård, P. M., Sørensen, P. H., Poulsen, N. K., Ravn, O., Hansen, L. K.
Pages: 301-306
Publication date: 1996

Host publication information
Title of host publication: Intelligent Control, 1996., Proceedings of the 1996 IEEE International Symposium on
Place of publication: Dearborn, Michigan, USA
Publisher: IEEE
ISBN (Print): 0-7803-2978-3
Electronic versions:
Nørgaard.pdf
DOIs: 10.1109/ISIC.1996.556218

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Source: orbit
Source-ID: 167343
Research output: Research - peer-review Article in proceedings – Annual report year: 1996

NNCTRL - a CANCSD toolkit for MATLAB®

A set of tools for computer-aided neuro-control system design (CANCSD) has been developed for the MATLAB environment. The tools can be used for construction and simulation of a variety of neural network based control systems. The design methods featured in the toolkit are: direct inverse control, internal model control, feedforward, feedback linearization, optimal control, instantaneous linearization, and nonlinear predictive control. Furthermore, the toolkit has been given a flexible design which allows for incorporation of the user's personal control algorithms.

General information
State: Published
Organisations: Department of Automation
Contributors: Nørgård, P. M., Ravn, O., Poulsen, N. K., Hansen, L. K.
Pages: 368-373
Publication date: 1996

Host publication information
Title of host publication: Proceedings of the 1996 IEEE Symposium on Computer-Aided Control System Design
Publisher: IEEE
ISBN (Print): 07-80-33032-3
Electronic versions:
Nørgaard.pdf
DOIs: 10.1109/CACSD.1996.555320

Bibliographical note
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Predictive Control Relevant Prefiltering

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Hansen, A. D., Poulsen, N. K.
Number of pages: 40
Publication date: 1996

Publication information
Publisher: Department of Mathematical Modelling, Technical University of Denmark
Original language: English
Source: orbit
Source-ID: 200922
Research output: Research - peer-review : Report – Annual report year: 1996

Stokastisk Adaptiv Regulering, del 4: Adaptive systemer, volume 4

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K.
Publication date: 1996

Publication information
Original language: Danish
Source: orbit
Source-ID: 164947
Research output: Research - peer-review : Book – Annual report year: 1996

The NNSYSID Toolbox - A MATLAB Toolbox for System Identification with Neural Networks
To assist the identification of nonlinear dynamic systems, a set of tools has been developed for the MATLAB(R) environment. The tools include a number of different model structures, highly effective training algorithms, functions for validating trained networks, and pruning algorithms for determination of optimal network architectures. The toolbox should be regarded as a nonlinear extension to the system identification toolbox provided by The MathWorks, Inc. This paper gives a brief overview of the entire collection of toolbox functions

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Automation, Department of Electrical Engineering, Cognitive Systems, Mathematical Statistics
Contributors: Nørgård, P. M., Ravn, O., Hansen, L. K., Poulsen, N. K.
Pages: 374-379
Publication date: 1996

Host publication information
Title of host publication: Proceedings of the 1996 IEEE Symposium on Computer-Aided Control System Design
Place of publication: Dearborn, Michigan, USA
Publisher: IEEE
ISBN (Print): 0-7803-3032-3
Electronic versions:
Nørgaard.pdf
DOIs:
10.1109/CACSD.1996.555321

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Source: orbit
Tracking Keeping Systems with Predictive Control

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Hansen, A. D., Poulsen, N. K.
Number of pages: 27
Publication date: 1996

Publication information
Publisher: Department of Mathematical Modelling, Technical University of Denmark
Original language: English
Source: orbit
Source-ID: 200921
Research output: Research - peer-review › Report – Annual report year: 1996

A Pitch regulated variable speed wind turbine

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Ma, X., Poulsen, N. K., Bindner, H.
Publication date: 1995

Publication information
Publisher: imsordth
Original language: English
Source: orbit
Source-ID: 201097
Research output: Research - peer-review › Report – Annual report year: 1995

Estimation of Wind Speed in Connection to a Wind Turbine
The wind speed varies over the rotor plane of wind turbine making it impossible to determine from a single wind speed measurement taken by an anemometer. However, in this paper the wind speed on the rotor plane will be estimated by using a wind turbine as a wind measuring device. To realize the idea, a knowledge of the system characteristics is required, therefore the fundamental relations and principles of system dynamics will be presented. Several estimation methods such as Newton-Raphson method, Kalman filter method and extended Kalman filter method will be investigated in the paper.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Ma, X., Poulsen, N. K., Bindner, H.
Publication date: 1995

Publication information
Publisher: Informatics and Mathematical Modelling, Technical University of Denmark, DTU
Original language: English
Keywords: Extended Kalman filter, Kalman filter, Estimation of wind speed, Wind turbine, Newton-Raphson method
Electronic versions: imm2796.ps
Source: orbit
Source-ID: 201096
Research output: Research - peer-review › Report – Annual report year: 1995

Generalized predictive control in the delta-domain
This paper describes new approaches to generalized predictive control formulated in the delta (δ) domain. A new δ-domain version of the continuous-time emulator-based predictor is presented. It produces the optimal estimate in the deterministic case whenever the predictor order is chosen greater than or equal to the number of future predicted samples, however a “good” estimate is usually obtained in a much longer range of samples. This is particularly advantageous at fast sampling rates where a “conventional” predictor is bound to become very computationally
demanding. Two controllers are considered: one having a well-defined limit as the sampling period tends to zero, the other being a close approximation to the conventional discrete-time GPC. Both algorithms are discrete in nature and well-suited for adaptive control. The fact, that δ-domain model are used does not introduce an approximation since such a model can be obtained by an exact sampling of a continuous-time model.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Lauritsen, M. B., Jensen, M. R., Poulsen, N. K.
Pages: 3709-3713
Publication date: 1995

Host publication information
Title of host publication: Proceedings of the American Control Conference
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Bibliographical note
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Source: orbit
Source-ID: 200200
Research output: Research - peer-review › Article in proceedings – Annual report year: 1995

Level and Rate Constraints in Predictive Control

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Hansen, A. D., Poulsen, N. K.
Publication date: 1995

Publication information
Publisher: imsordth
Original language: English
Source: orbit
Source-ID: 200924
Research output: Research - peer-review › Report – Annual report year: 1995

Methodologies for the Analysis of Data from Sewers and Wastewater Treatment Plants

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling, Department of Environmental Science and Engineering, Krüger A/S
Contributors: Nielsen, M. K., Carstensen, J., Madsen, H., Poulsen, N. K., Harremoës, P.
Publication date: 1995

Host publication information
Title of host publication: Proceedings of Nordic Seminar on Nitrogen removal from Municipal Wastewater
Place of publication: Otaniemi
Publisher: Helsinki University
Source: orbit
Source-ID: 318453
Research output: Research - peer-review › Article in proceedings – Annual report year: 1995

Methodologies for the Analysis of Data From Sewersm and Wastewater Treatment Plants

General information
State: Published
Model Reduction and Gain Scheduling Control

Optimal Prediction in the Delta-Domain

Emulator-Based GPC in the Delta Domain

Emulator-Based Prediction in the Delta-Domain
Identification of wastewater treatment processes for nutrient removal on a full-scale WWTP by statistical methods

The introduction of on-line sensors of nutrient salt concentrations on wastewater treatment plants opens a wide new area of modelling wastewater processes. Time series models of these processes are very useful for gaining insight in real time operation of wastewater treatment systems which deal with variable influent flows and pollution loads. In this paper nonlinear time series models describing the variations of the ammonia and nitrate concentrations in the aeration tanks of a biological nutrient removal WWTP are established. The models proposed herein are identified by combining well-known theory of the processes, i.e. including prior knowledge, with the significant effects found in data by using statistical identification methods. Rates of the biochemical and hydraulic processes are identified by statistical methods and the related constants for the biochemical processes are estimated assuming Monod kinetics. The models only include those hydraulic and kinetic parameters, which have shown to be significant in a statistical sense, and hence they can be quantified. The application potential of these models is on-line control, because the present state of the plant is given by the variables of the models which are continuously updated as new information from the on-line sensors becomes available.
ML-estimation for Delta Based State Space Models

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics, Automation, Department of Electrical Engineering
Contributors: Jensen, M. R., Poulsen, N. K., Ravn, O.
Pages: 663-668
Publication date: 1994

Host publication information

ML-estimation for Delta Based State Space Models
Modelling and Control of a Wind Turbine

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Ma, X., Poulsen, N. K., Bindner, H.
Publication date: 1994

Publication information
Publisher: Institute of Mathematical Statistics and Operations Research (IMSOR), The Technical University of Denmark
Original language: English
Source: orbit
Source-ID: 200369
Research output: Research - peer-review › Article in proceedings – Annual report year: 1994

Pay-Load Estimation of a Flexible Robot

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling, Automation, Department of Electrical Engineering
Contributors: Rostgaard, M., Poulsen, N. K., Ravn, O.
Publication date: 1994

Publication information
Publisher: immdtu
Original language: English
Source: orbit
Source-ID: 201029
Research output: Research - peer-review › Report – Annual report year: 1994

Prediction using the Delta Operator

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Rostgaard, M., Lauritsen, M. B., Poulsen, N. K.
Publication date: 1994

Publication information
Publisher: Department of Mathematical Modelling, Technical University of Denmark
Original language: English
Source: orbit
Source-ID: 201030
Research output: Research - peer-review › Report – Annual report year: 1994

Quadratic Controllers Based on Long Range Prediction

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics, Automation, Department of Electrical Engineering
Contributors: Jensen, M. R., Lauritsen, M. B., Poulsen, N. K., Ravn, O.
Publication date: 1994

Publication information
Publisher: Department of Mathematical Modelling, Technical University of Denmark
Original language: English
Spectral factorization using the delta operator

In recent years many papers have been published about the gamma-operator, mostly caused by the better numerical properties and the rapprochement between continuous and discrete time. A major problem within the LQG-design of a delta-based input-output relation has been how to spectral-factorize in an efficient way. The discrete-time method of Kucera will not be applied since numerical word-length characteristics will be poor for fast sampling rates. In this paper a new approach is considered. A new gamma-operator (Tustin operator) is introduced, in order to make an iterative and numerical stable solution to the spectral factorization problem. The key idea is to use the gamma-operator resembled by its behavior to the differential operator.

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling, Automation, Department of Electrical Engineering
Contributors: Rostgaard, M., Poulsen, N. K., Ravn, O.
Pages: 293-301
Publication date: 1994
Peer-reviewed: Yes

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Journal: Systems and Control Letters
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Issue number: 5
ISSN (Print): 0167-6911
Ratings:
BFI (2019): BFI-level 1
Web of Science (2019): Indexed yes
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 3.4 SJR 1.939 SNIP 1.742
Web of Science (2017): Impact factor 2.656
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.64 SJR 2.041 SNIP 1.84
Web of Science (2016): Impact factor 2.55
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 3.11 SJR 2.277 SNIP 1.928
Web of Science (2015): Impact factor 1.908
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 3.1 SJR 1.908 SNIP 1.854
Web of Science (2014): Impact factor 2.059
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 3.46 SJR 2.019 SNIP 1.978
Web of Science (2013): Impact factor 1.886
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.82 SJR 1.85 SNIP 1.666
Web of Science (2012): Impact factor 1.667
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): CiteScore 2.58 SJR 2.148 SNIP 1.953
Web of Science (2011): Impact factor 1.222
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.777 SNIP 1.988
Web of Science (2010): Impact factor 1.412
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.585 SNIP 2.401
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 3.01 SNIP 2.108
Scopus rating (2007): SJR 2.331 SNIP 1.725
Scopus rating (2006): SJR 1.85 SNIP 1.669
Scopus rating (2005): SJR 1.046 SNIP 1.47
Scopus rating (2004): SJR 1.664 SNIP 1.38
Scopus rating (2003): SJR 2.235 SNIP 1.736
Scopus rating (2002): SJR 3.549 SNIP 1.822
Scopus rating (2001): SJR 3.307 SNIP 1.714
Scopus rating (2000): SJR 1.092 SNIP 1.65
Scopus rating (1999): SJR 1.144 SNIP 1.267
Original language: English
Keywords: δ-operator, Tustin operator, Spectral factorization, LQD design, Adaptive control
URLs:
http://www2.imm.dtu.dk/pubdb/p.php?2780
Source: orbit
Source-ID: 199786
Research output: Research - peer-review › Journal article – Annual report year: 1994

Udvikling af on-line gaschromatografisk målesystem til bestemmelse af VFA

General information
State: Published
Organisations: Department of Biotechnology, Bioscience and Technology, Department of Systems Biology, Automation, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Torp, S., Ahring, B. K., Jungersen, G., Ravn, O., Poulsen, N. K.
Publication date: 1994

Publication information
Publisher: Bioteknik, Dansk Teknologisk Institut
Original language: Danish
Source: orbit
Source-ID: 201054
Research output: Research - peer-review › Report – Annual report year: 1994

A rapprochement Between Discrete-time operators

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics, Automation, Department of Electrical Engineering
Contributors: Jensen, M. R., Poulsen, N. K., Ravn, O.
Pages: 426-431
Publication date: 1993

Host publication information
Title of host publication: European Control Conference (ECC93), Groningen, The Netherlands (Technical report, IMSOR, DTU; No. no. 15/92).
Source: orbit
Source-ID: 200370
Research output: Research - peer-review › Article in proceedings – Annual report year: 1993

A short introduction to Matlab

General information
State: Published
General predictive control using the delta operator
This paper deals with two-discrete-time operators, the conventional forward shift-operator and the \( \delta \)-operator. Both operators are treated in view of construction of suitable solutions to the Diophantine equation for the purpose of prediction. A general step-recursive scheme is presented. Finally a general predictive control (GPC) is formulated and applied adaptively to a continuous-time plant.

General Predictive Control Using the Delta Operator

Grey box modelling in two time domains of a wastewater pilot scale plant
Modelling of a One Degree of Freedom Flexible Link

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics, Automation, Department of Electrical Engineering
Contributors: Jensen, M. R., Poulsen, N. K., Ravn, O.
Publication date: 1993

Stochastic Modelling and adaptive LQG control of a ship

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics, Automation, Department of Electrical Engineering
Contributors: Jensen, M. R., Poulsen, N. K., Thygesen, B. G., Ravn, O.
Pages: 397-400
Publication date: 1993

Host publication information
Title of host publication: 12'th IFAC World Congress, Sydney, Australia
Source: orbit
Source-ID: 200371
Research output: Research - peer-review › Article in proceedings – Annual report year: 1993

Determination of Flutter Derivatives for the Great Belt Bridge
A new method which combines control theory and system identification techniques has been used to extract flutter derivatives from section model tests for the Great Belt East Bridge. Tests were conducted by exciting the section model simultaneously in vertical and torsional modes of vibration. Tests were primarily conducted in smooth flow for various ratios between vertical and torsional frequencies of vibration. Limited testing was also conducted in turbulent flow and for different angles of attack. The analysis technique described allowed extraction of seven aerodynamic derivatives including coupled motion derivatives from a simple set of tests. This paper describes the control theory and system identification approach used and discusses the limitations encountered. Results are compared with flutter derivatives obtained by other researchers. The method offers a reasonably robust technique for automating the process of extracting aerodynamic derivatives from recorded time histories of coupled vertical and torsional motion.

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K., Damsgaard, A., Reinhold, T. A.
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<th>Year</th>
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<th>Scopus rating</th>
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<td>Indexed yes</td>
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<td>Impact factor 1.789</td>
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<td>2006</td>
<td>BFI-level 1</td>
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<td>Indexed yes</td>
<td>Impact factor 1.237</td>
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**Publication information**

- **Journal**: Journal of Wind Engineering and Industrial Aerodynamics
- **Volume**: 41
- **Issue number**: 1-3
- **ISSN (Print)**: 0167-6105

**Ratings**

- **BFI (2019)**: BFI-level 1
- **Web of Science (2019)**: Indexed yes
- **BFI (2018)**: BFI-level 1
- **Web of Science (2018)**: Indexed yes
- **BFI (2017)**: BFI-level 1
- **Scopus rating (2017)**: CiteScore 3.42 SJR 1.264 SNIP 2.071
- **Web of Science (2017)**: Impact factor 2.689
- **Web of Science (2016)**: Indexed yes
- **BFI (2016)**: BFI-level 1
- **Scopus rating (2016)**: CiteScore 2.61 SJR 0.992 SNIP 1.929
- **Web of Science (2016)**: Impact factor 2.049
- **Web of Science (2015)**: Indexed yes
- **BFI (2015)**: BFI-level 1
- **Scopus rating (2015)**: CiteScore 2.51 SJR 0.976 SNIP 1.939
- **Web of Science (2015)**: Impact factor 2.024
- **Web of Science (2014)**: Indexed yes
- **BFI (2014)**: BFI-level 1
- **Scopus rating (2014)**: CiteScore 2.13 SJR 0.902 SNIP 2.282
- **Web of Science (2014)**: Impact factor 1.414
- **Web of Science (2013)**: Indexed yes
- **BFI (2013)**: BFI-level 1
- **Scopus rating (2013)**: CiteScore 2.43 SJR 0.8 SNIP 2.68
- **Web of Science (2013)**: Impact factor 1.698
- **ISI indexed (2013)**: ISI indexed yes
- **Web of Science (2012)**: Indexed yes
- **BFI (2012)**: BFI-level 1
- **Scopus rating (2012)**: CiteScore 1.81 SJR 0.642 SNIP 2.431
- **Web of Science (2012)**: Impact factor 1.342
- **ISI indexed (2012)**: ISI indexed yes
- **Web of Science (2011)**: Indexed yes
- **BFI (2011)**: BFI-level 1
- **Scopus rating (2011)**: CiteScore 2.3 SJR 0.902 SNIP 3.236
- **Web of Science (2011)**: Impact factor 1.119
- **ISI indexed (2011)**: ISI indexed yes
- **Web of Science (2010)**: Indexed yes
- **BFI (2010)**: BFI-level 1
- **Scopus rating (2010)**: SJR 0.907 SNIP 2.197
- **Web of Science (2010)**: Impact factor 1.213
- **Web of Science (2010)**: Indexed yes
- **BFI (2009)**: BFI-level 1
- **Scopus rating (2009)**: SJR 0.737 SNIP 1.406
- **BFI (2008)**: BFI-level 1
- **Scopus rating (2008)**: SJR 0.708 SNIP 2.137
- **Web of Science (2008)**: Indexed yes
- **Scopus rating (2007)**: SJR 0.789 SNIP 2.272
Adaptive Optimization of the indicated efficiency in spark ignition engines

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics, Automation, Department of Electrical Engineering
Contributors: Bechmann, H., Poulsen, N. K., Hendricks, E.
Publication date: 1992

Publication information
Publisher: Institute of Mathematical Statistics and Operations Research (IMSOR), The Technical University of Denmark
Original language: English
Source: orbit
Source-ID: 199769
Research output: Research - peer-review › Conference article – Annual report year: 1992

A rapprochement Between Discrete-time operators

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics, Automation, Department of Electrical Engineering
Contributors: Jensen, M. R., Poulsen, N. K., Ravn, O.
Publication date: 1992

Publication information
Publisher: Institute of Mathematical Statistics and Operations Research (IMSOR), The Technical University of Denmark
Original language: English
Source: orbit
Source-ID: 200882
Research output: Research - peer-review › Report – Annual report year: 1992

Calculas for stochastic systems based on the delta operator.

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Thygesen, B. G., Poulsen, N. K., Holst, J.
Publication date: 1992
Identification of wastewater processes using nonlinear grey box models

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Carstensen, J., Madsen, H., Poulsen, N. K.
Publication date: 1992

Methods for quantification of the estimator uncertainty in recursive estimation of restricted

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Sejloring, K., Madsen, H., Henningsen, A., Poulsen, N. K.
Publication date: 1992

Recursive forgetting algorithms
In the first part of the paper, a general forgetting algorithm is formulated and analysed. It contains most existing forgetting schemes as special cases. Conditions are given ensuring that the basic convergence properties will hold. In the second part of the paper, the results are applied to a specific algorithm with selective forgetting. Here, the forgetting is non-uniform in time and space. The theoretical analysis is supported by a simulation example demonstrating the practical performance of this algorithm

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Parkum, J., Poulsen, N. K., Holst, J.
Pages: 109-128
Publication date: 1992
Peer-reviewed: Yes
Sampling of a continuous time linear quadratic criterion

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Thygesen, B. G., Poulsen, N. K., Holst, J.
Publication date: 1992

Publication information
Publisher: Institute of Mathematical Statistics and Operations Research (IMSOR), The Technical University of Denmark
Original language: English
Source: orbit
Source-ID: 201050
Research output: Research - peer-review › Report – Annual report year: 1992

Spectral factorization using the delta operator

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics, Automation, Department of Electrical Engineering
Contributors: Jensen, M. R., Poulsen, N. K., Ravn, O.
Publication date: 1992

Publication information
Publisher: Institute of Mathematical Statistics and Operations Research (IMSOR), The Technical University of Denmark
Original language: English
Source: orbit
Source-ID: 201034
Research output: Research - peer-review › Report – Annual report year: 1992

Analysis of Forgetting Methods

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Parkum, J., Poulsen, N. K., Holst, J.
Pages: 134-189
Publication date: 1991

Host publication information
Title of host publication: The 9th IFAC/IFORS Symposium on Identification and System Parameter Estimation, Budapest, Hungary
Source: orbit
Source-ID: 200314
Research output: Research - peer-review › Article in proceedings – Annual report year: 1991

Approximative results for the zero location in sampled dynamical systems

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Thygesen, B. G., Poulsen, N. K., Holst, J.
Publication date: 1991

Publication information
Publisher: Institute of Mathematical Statistics and Operations Research (IMSOR), The Technical University of Denmark
Original language: English
Source: orbit
Source-ID: 201052
Research output: Research - peer-review › Report – Annual report year: 1991
Introduktion til simulationssystemet (ACSL)

Limit results for sampled transfer functions

Analysis of On-line Estimation Methods designed for the time-varying case

A Robust Self-Tuning Controller for Time Varying Systems
Deterministic Convergence of Recursive Forgetting Algorithms

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Parkum, J., Poulsen, N. K., Holst, J.
Publication date: 1990

Publication information
Publisher: Institute of Mathematical Statistics and Operations Research (IMSOR), The Technical University of Denmark
Original language: English
Source: orbit
Source-ID: 201014
Research output: Research - peer-review › Report – Annual report year: 1990

Identifiability Analysis and Calibration of Models for Waste Water Treatment Processes

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Parkum, J., Poulsen, N. K.
Publication date: 1990

Publication information
Publisher: Institute of Mathematical Statistics and Operations Research (IMSOR), The Technical University of Denmark
Original language: English
Source: orbit
Source-ID: 201013
Research output: Research - peer-review › Report – Annual report year: 1990

Selective Forgetting in Adaptive procedures

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Parkum, J., Poulsen, N. K., Holst, J.
Pages: 180-185
Publication date: 1990

Host publication information
Title of host publication: The 11th IFAC World Congress in Tallinn
Source: orbit
Source-ID: 200315
Research output: Research - peer-review › Article in proceedings – Annual report year: 1990

System Identification - a Sensitivity Approach

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K., Holst, J., Parkum, J.
Publication date: 1990

Host publication information
Title of host publication: Proceedings of the Nordic CACE Symposium, Lyngby
Source: orbit
Source-ID: 200507
Research output: Research › Article in proceedings – Annual report year: 1990

Simultaneous Estimation of Innovations variance and States in a Dynamic System

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Adaptive Minimum Energy Control of Large Diesel Engines

General information
State: Published
Organisations: Automation, Department of Electrical Engineering, Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Hendricks, E., Holst, J., Poulsen, N. K., Joensen, H.
Pages: 231-236
Publication date: 1986

Host publication information
Title of host publication: IFAC Workshop on Adaptive Systems in Control and Signal Processing, Lund, Sweden
Source: orbit
Source-ID: 200143
Research output: Research - peer-review › Article in proceedings – Annual report year: 1986

Minimum Energy Control of Large Diesel Engines

General information
State: Published
Organisations: Automation, Department of Electrical Engineering, Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Hendricks, E., Poulsen, N. K.
Publication date: 1986
Peer-reviewed: Yes

Publication information
Journal: SAE technical paper
Volume: 861191
Original language: English
URLs:
http://www2.imm.dtu.dk/pubdb/p.php?2746
Source: orbit
Source-ID: 199626
Research output: Research - peer-review › Journal article – Annual report year: 1986

A Robust Self Tuning Controller for Timevarying Dynamic Systems

General information
State: Published
Organisations: Department of Informatics and Mathematical Modeling, Mathematical Statistics
Contributors: Holst, J., Poulsen, N. K.
Pages: 1773-1778
Publication date: 1985

Host publication information
Title of host publication: Identification and System Parameter Estimation, York, UK
Source: orbit
Source-ID: 200153
Research output: Research - peer-review › Article in proceedings – Annual report year: 1985

Robust Self Tuning Controllers
Self Tuning Control of Abruptly Changing Dynamic Systems

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K., Holst, J.
Pages: 91-113
Publication date: 1984

Host publication information
Title of host publication: Symposium i anvendt statistik 1984
Source: orbit
Source-ID: 200508
Research output: Research › Article in proceedings – Annual report year: 1984

Self Tuning Control of Plants with abrupt changes

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K., Holst, J.
Pages: 144-149
Publication date: 1984

Host publication information
Title of host publication: IFAC World Congress, Budapest, Hungary
Source: orbit
Source-ID: 200348
Research output: Research - peer-review › Article in proceedings – Annual report year: 1984

Robust Self Tuning Controllers in Non Stationary Situations

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K., Holst, J.
Pages: 197-217
Publication date: 1982
Peer-reviewed: Yes

Publication information
Journal: Recerche di Automatica
Volume: 13
Issue number: 2
Original language: English
URLs:
http://www2.imm.dtu.dk/pubdb/p.php?2760
Robust Self Tuning Controllers in Non Stationary Situations

General information
State: Published
Organisations: Mathematical Statistics, Department of Informatics and Mathematical Modeling
Contributors: Poulsen, N. K., Holst, J.
Pages: 257-279
Publication date: 1982

Host publication information
Title of host publication: Workshop on Adaptive Control, Florence, Italy
Source: orbit
Source-ID: 200349
Research output: Research - peer-review › Article in proceedings – Annual report year: 1982

Projects:

Model Predictive Control in Urban Systems
Svensen, J. L., PhD Student, Department of Applied Mathematics and Computer Science
Poulsen, N. K., Main Supervisor, Department of Applied Mathematics and Computer Science
Falk, A. K. V., Supervisor, Department of Applied Mathematics and Computer Science
Madsen, H., Supervisor, Department of Environmental Science and Engineering
Niemann, H. H., Supervisor, Department of Electrical Engineering
Samfinansieret - Andet
15/09/2017 → 14/09/2020
Award relations: Model Predictive Control in Urban Systems
Project: PhD

Stochastic Dynamic Optimization and Control Theory
Brok, N. L., PhD Student, Department of Applied Mathematics and Computer Science
Madsen, H., Main Supervisor, Department of Applied Mathematics and Computer Science
Jørgensen, J. B., Supervisor, Department of Applied Mathematics and Computer Science
Poulsen, N. K., Supervisor, Department of Applied Mathematics and Computer Science
Institut stipendie (DTU)
01/09/2017 → 14/12/2020
Award relations: Stochastic Dynamic Optimization and Control Theory
Project: PhD

Human Behavior of Track Pilot
Master Thesis Project
Stockmarr, A., Main Supervisor, Department of Applied Mathematics and Computer Science, Statistics and Data Analysis
Poulsen, N. K., Supervisor, Department of Applied Mathematics and Computer Science, Dynamical Systems
29/08/2016 → 07/02/2017
Keywords: Time Series Analysis, Navigation, PID controller
Collaborators: FORCE Technology
Project: Research

Learning-based Model Predictive Control of Spray Dryers
Miklos, R., PhD Student, Department of Electrical Engineering
Niemann, H. H., Main Supervisor, Department of Electrical Engineering
Jørgensen, J. B., Supervisor, Department of Applied Mathematics and Computer Science
Petersen, L. N., Supervisor, Scientific Computing
Poulsen, N. K., Supervisor, Department of Applied Mathematics and Computer Science
Utzen, C., Supervisor
Industrial PhD
01/01/2017 → 31/12/2019
Award relations: Learning-based Model Predictive Control of Spray Dryers
Efficient Operation of Energy Grids
Banis, F., PhD Student, Department of Applied Mathematics and Computer Science
Poulsen, N. K., Main Supervisor, Department of Applied Mathematics and Computer Science
Guericke, D., Supervisor, Department of Applied Mathematics and Computer Science
Madsen, H., Supervisor, Department of Environmental Science and Engineering
Samfinansieret - Andet
01/12/2016 → 30/11/2019
Award relations: Efficient Operation of Energy Grids
Project: PhD

Ulineær optimal robust styring og vindmølle regulering
Thomsen, S. C., PhD Student, Department of Informatics and Mathematical Modeling
Poulsen, N. K., Main Supervisor, Department of Informatics and Mathematical Modeling
Niemann, H. H., Supervisor
Jørgensen, J. B., Examiner, Department of Informatics and Mathematical Modeling
Stoustrup, J., Examiner
DTU-lønnet stipendie
15/10/2006 → 29/09/2010
Award relations: Ulineær optimal robust styring og vindmølle regulering
Project: PhD

Integreret Aeroservoelastisk Analyse og Design af Vindmøller
Sønderby, I. B., PhD Student, Department of Wind Energy
Hansen, M. H., Main Supervisor, Department of Wind Energy
Poulsen, N. K., Examiner
Kanev, S., Examiner
Riziotis, V. A., Examiner
Institut, samfinansiering
01/09/2009 → 20/09/2013
Award relations: Integreret Aeroservoelastisk Analyse og Design af Vindmøller
Project: PhD

Data assimilering og autokalibrering i 2D/3D hydrodynamisk numerisk modellering af det marine miljø
Sørensen, J. V. T., PhD Student, Department of Informatics and Mathematical Modeling
Madsen, H., Main Supervisor, Department of Informatics and Mathematical Modeling
Madsen, H., Supervisor
Poulsen, N. K., Examiner, Department of Informatics and Mathematical Modeling
Cañizares, R., Examiner
Heemink, A. W., Examiner
Erhvervsforskerordningen
01/04/2000 → 17/05/2004
Award relations: Data assimilering og autokalibrering i 2D/3D hydrodynamisk numerisk modellering af det marine miljø
Project: PhD

Regulering af systemer med begrænsninger
Bak, M., PhD Student, Department of Automation
Ravn, O., Main Supervisor, Department of Electrical Engineering
Poulsen, N. K., Supervisor, Department of Applied Mathematics and Computer Science
Jannerup, O. E., Examiner, Department of Electrical Engineering
Rasmussen, H., Examiner
Raymond, H., Examiner
DTU-Su Stipendium, Eksperiment
01/09/1997 → 18/04/2001
Award relations: Regulering af systemer med begrænsninger
Project: PhD

Modellering og Prædiktiv Styring af Spildevandssystemer
Bechmann, H., PhD Student, Center for Bachelor of Engineering Studies
Madsen, H., Main Supervisor, Department of Applied Mathematics and Computer Science
Poulsen, N. K., Supervisor, Department of Applied Mathematics and Computer Science
Erhvervsforskerordningen
01/05/1996 → 28/04/2000
Award relations: Modellering og Prædiktiv Styring af Spildevandssystemer
Project: PhD

Stokastisk Prædiktiv Kontrol i Komplekse Systemer
Nielsen, T. S., PhD Student, Department of Informatics and Mathematical Modeling
Madsen, H., Main Supervisor, Department of Informatics and Mathematical Modeling
Holst, J., Supervisor
Poulsen, N. K., Examiner, Department of Informatics and Mathematical Modeling
Bidstrup, N., Examiner
Egardt, B., Examiner
Kandidatstipendium ansat på DT
01/02/1996 → 14/11/2002
Award relations: Stokastisk Prædiktiv Kontrol i Komplekse Systemer
Project: PhD

Aktiv kontrol af udstrålet stød fra vibrerende strukturer
Mørkholt, J., PhD Student
Jacobsen, F., Main Supervisor, Department of Electrical Engineering
Poulsen, N. K., Examiner
DTU-Su Stipendium, Eksperiment
01/02/1996 → 17/11/1999
Award relations: Aktiv kontrol af udstrålet stød fra vibrerende strukturer
Project: PhD

Identifikation af modeller for kedel- og varmeanlæg
Hansen, L. H., PhD Student, Department of Informatics and Mathematical Modeling
Madsen, H., Main Supervisor, Department of Informatics and Mathematical Modeling
Hansen, P. E., Examiner
Poulsen, N. K., Examiner, Department of Informatics and Mathematical Modeling
Erhvervsforskerordningen
01/06/1994 → 11/02/1998
Award relations: Identifikation af modeller for kedel- og varmeanlæg
Project: PhD

Identifikation/adaptiv regulering af systemer med ukendt modelstruktur og væsentlige ulineariteter
Wagner, C. H., PhD Student
Conrad, F., Main Supervisor, Department of Mechanical Engineering
Poulsen, N. K., Examiner
Akademiet for de Tekniske Videnskaber
01/04/1991 → 24/01/1994
Award relations: Identifikation/adaptiv regulering af systemer med ukendt modelstruktur og væsentlige ulineariteter
Project: PhD

Market Mechanisms for the Integration of Distributed Energy Resources
De Zotti, G., PhD Student, Department of Applied Mathematics and Computer Science
Poulsen, N. K., Main Supervisor, Department of Applied Mathematics and Computer Science
Morales González, J. M., Supervisor, Department of Informatics and Mathematical Modeling
Pourmousavi Kani, S. A., Supervisor, Department of Applied Mathematics and Computer Science
Madsen, H., Supervisor, Department of Applied Mathematics and Computer Science
Samfinansieret - Andet
01/04/2016 → 31/03/2019
Award relations: Market Mechanisms for the Integration of Distributed Energy Resources
Project: PhD

Nonlinear Model Predictive Control for Oil Reservoirs
Ritschel, T. K. S., PhD Student, Department of Applied Mathematics and Computer Science
Jørgensen, J. B., Main Supervisor, Department of Applied Mathematics and Computer Science
Capolei, A., Supervisor, Department of Applied Mathematics and Computer Science
Fault Diagnosis and Optimal Control of Electro - Mechanical systems

Sekunda, A. K., PhD Student, Department of Electrical Engineering
Niemann, H. H., Main Supervisor, Department of Electrical Engineering
Poulsen, N. K., Supervisor
Santos, I., Supervisor
Galeazzi, R., Examiner, Department of Electrical Engineering
Kalleæe, C. S., Examiner
Kinninger, M., Examiner

Institut stipendie (DTU)
15/12/2014 → 03/05/2018
Award relations: Fault Diagnosis and Optimal Control of Electro - Mechanical systems
Project: PhD

Economic Model Predictive Control for Spray Drying Plants

Petersen, L. N., PhD Student
Jørgensen, J. B., Main Supervisor
Niemann, H. H., Supervisor
Poulsen, N. K., Supervisor
Utzen, C., Supervisor
Huusom, J. K., Examiner
Engell, S., Examiner
Pannocchia, G., Examiner

ErhvervPhD-ordningen VTU
01/10/2012 → 22/06/2016
Award relations: Economic Model Predictive Control for Spray Drying Plants
Project: PhD

Self-Organising Distributed Control of a Distributed Energy System with a High Penetration of Renewable Energy

Gehrke, O., PhD Student, Department of Electrical Engineering
Poulsen, N. K., Main Supervisor, Department of Informatics and Mathematical Modeling
Bindner, H. W., Supervisor, Department of Electrical Engineering
Madsen, H., Supervisor, Department of Informatics and Mathematical Modeling
Nielsen, A. H., Supervisor, Department of Electrical Engineering
Lind, M., Examiner, Department of Electrical Engineering
Degner, T., Examiner
McArthur, S., Examiner

Risø (Len)
01/04/2005 → 17/02/2010
Award relations: Self-Organising Distributed Control of a Distributed Energy System with a High Penetration of Renewable Energy
Project: PhD

Data assimilation in atmosphere dispersion of radioactive material

Drews, M., PhD Student, Department of Management Engineering
Madsen, H., Main Supervisor, Department of Applied Mathematics and Computer Science
Lauritzen, B., Supervisor, Center for Nuclear Technologies
Poulsen, N. K., Examiner, Department of Applied Mathematics and Computer Science
Finck, R. R., Examiner
Holst, J., Examiner

Risø (Len)
01/10/2000 → 18/03/2005
Award relations: Data assimilation in atmosphere dispersion of radioactive material
Project: PhD
Analysis of dynamic behaviour of electric power systems with large amount of wind power
Akhmatov, V., PhD Student, Department of Electrical Engineering
Nielsen, A. H., Main Supervisor, Department of Electrical Engineering
Nielsen, J. N., Supervisor, Department of Electrical Engineering
Poulsen, N. K., Supervisor
Hansen, M. O. L., Examiner
Gertmar, L., Examiner
Jenkins, N., Examiner
Erhvervsforskerordningen
15/11/1999 → 18/11/2003
Award relations: Analysis of dynamic behaviour of electric power systems with large amount of wind power
Project: PhD

Possible Power of Downregulated Offshore Wind power plants
Göçmen, T., PhD Student, Department of Wind Energy
Giebel, G., Main Supervisor, Department of Wind Energy
Poulsen, N. K., Supervisor, Department of Applied Mathematics and Computer Science
Sørensen, P. E., Supervisor, Department of Wind Energy
Sørensen, J. N., Examiner, Department of Wind Energy
Apt, J., Examiner
Johansen, K., Examiner
Apt, J., Examiner
Johansen, K., Examiner
Offentlig finansiering
15/12/2012 → 07/04/2016
Award relations: Possible Power of Downregulated Offshore Wind power plants
Project: PhD

Optimal and Reproducible Operation of Batch Processes
Bonné, D., PhD Student, Department of Chemical and Biochemical Engineering
Jergensen, S. B., Main Supervisor, Department of Chemical and Biochemical Engineering
Poulsen, N. K., Examiner, Department of Applied Mathematics and Computer Science
Andersen, H. W., Examiner
Bonvin, D., Examiner
Apt, J., Examiner
Anden sektorministeriel finans
01/08/2000 → 08/07/2005
Award relations: Optimal and Reproducible Operation of Batch Processes
Project: PhD

Sensor Design and Control Algorithm for Flaps on Wind Turbine Blades
Castaignet, D. B., PhD Student
Buhl, T., Main Supervisor, Department of Wind Energy
Poulsen, N. K., Supervisor
Wedel-Heinen, J. J., Supervisor
Knudsen, T., Examiner
van Dam, C. P., Examiner
Ansat eksternt
01/12/2008 → 23/05/2012
Award relations: Sensor Design and Control Algorithm for Flaps on Wind Turbine Blades
Project: PhD

Grey box Modelling of Hydraulic Systems
Thordarson, F. Ö., PhD Student
Madsen, H., Main Supervisor, Department of Informatics and Mathematical Modeling
Madsen, H., Supervisor
Poulsen, N. K., Examiner, Department of Informatics and Mathematical Modeling
Rasmussen, M. R., Examiner
Willems, P., Examiner
Forskningsrådsfinansiering
01/10/2007 → 23/02/2012
Award relations: Grey box Modelling of Hydraulic Systems
Digital styring og modellering af dynamiske systemer ved hurtig sampling.

Jensen, M. R., PhD Student, Department of Informatics and Mathematical Modeling

Poulsen, N. K., Main Supervisor, Department of Informatics and Mathematical Modeling

Forskningsrådsstipendium

01/03/1992 → 14/08/1995

Award relations: Digital styring og modellering af dynamiske systemer ved hurtig sampling.

Project: PhD

Robust control system design for a wind energy commersion system

Ma, X., PhD Student, Department of Informatics and Mathematical Modeling

Poulsen, N. K., Main Supervisor, Department of Informatics and Mathematical Modeling

Gammel ordning u/skema-SU


Award relations: Robust control system design for a wind energy commersion system

Project: PhD

Deltamodellering

Thygesen, B. G., PhD Student, Department of Informatics and Mathematical Modeling

Poulsen, N. K., Main Supervisor, Department of Informatics and Mathematical Modeling

Gammel ordning u/skema-SU

01/09/1990 → 30/05/1994

Award relations: Deltamodellering

Project: PhD

Robotteknik

Zhang, M., PhD Student

Conrad, F., Main Supervisor, Department of Mechanical Engineering

Poulsen, N. K., Examiner

Gammel ordning u/skema-SU

01/02/1990 → 12/09/1997

Award relations: Robotteknik

Project: PhD

Design and Control of Time-Varying Chimical Processes

Pedersen, K., PhD Student, Department of Chemical and Biochemical Engineering

Jørgensen, S. B., Main Supervisor, Department of Chemical and Biochemical Engineering

Olsson, L., Supervisor, Department of Biotechnology

Poulsen, N. K., Examiner, Department of Applied Mathematics and Computer Science

Brabrand, H., Examiner

Hagander, P., Examiner

Forskningsrådsstip.-SU, Eksp

01/09/1995 → 13/03/2002

Award relations: Design and Control of Time-Varying Chimical Processes

Project: PhD

Connection between control design and system identification

Lauritsen, M. B., PhD Student, Department of Informatics and Mathematical Modeling

Poulsen, N. K., Main Supervisor, Department of Informatics and Mathematical Modeling

Egardt, B., Examiner

DTU-Su Stipendium, Ekspirement

01/02/1994 → 24/07/1997

Award relations: Connection between control design and system identification

Project: PhD

Performance enhancement and load reduction on wind turbines using inflow measurements

Kragh, K. A., PhD Student, Risø National Laboratory for Sustainable Energy

Hansen, M. H., Main Supervisor, Department of Solid Mechanics

Larsen, T. J., Supervisor, Risø National Laboratory for Sustainable Energy
Optimizing control of integrated processes
Jørgensen, J. B., PhD Student, Department of Applied Mathematics and Computer Science
Jørgensen, S. B., Main Supervisor, Department of Chemical and Biochemical Engineering
Poulsen, N. K., Examiner, Department of Applied Mathematics and Computer Science
Marquardt, W., Examiner
Strand, S., Examiner
DTU-Su Stipendium, Eksperiment
01/08/1997 → 03/06/2005
Award relations: Optimizing control of integrated processes
Project: PhD

Stochastic Dynamic modelling of Oxigen
Jonsdottir, H., PhD Student, Department of Informatics and Mathematical Modeling
Madsen, H., Main Supervisor, Department of Informatics and Mathematical Modeling
Eliasson, J., Supervisor
Palsson, O. P., Supervisor, Department of Informatics and Mathematical Modeling
Poulsen, N. K., Examiner, Department of Informatics and Mathematical Modeling
Madsen, H., Examiner
Olsson, G., Examiner
DTU-Su Stipendium, Eksperiment
01/04/1997 → 08/02/2007
Award relations: Stochastic Dynamic modelling of Oxigen
Project: PhD

Stochastic modelling of nonlinear systems
Nielsen, J. N., PhD Student, Department of Informatics and Mathematical Modeling
Madsen, H., Main Supervisor, Department of Informatics and Mathematical Modeling
Poulsen, N. K., Examiner, Department of Informatics and Mathematical Modeling
Ljung, L., Examiner
DTU-Su Stipendium, Eksperiment
01/03/1996 → 29/03/2001
Award relations: Stochastic modelling of nonlinear systems
Project: PhD

Optimality and Robustness of Stochastic Adaptive Controllers
Thygesen, U. H., PhD Student, Department of Applied Mathematics and Computer Science
Poulsen, N. K., Main Supervisor, Department of Applied Mathematics and Computer Science
Madsen, H., Examiner
DTU-Su Stipendium, Eksperiment
01/09/1995 → 06/03/1999
Award relations: Optimality and Robustness of Stochastic Adaptive Controllers
Project: PhD

Mechatronic approach in design and modelling of robotic manipulators
Baungaard, J. R., PhD Student, Department of Automation
Ravn, O., Main Supervisor, Department of Electrical Engineering
Poulsen, N. K., Supervisor, Department of Applied Mathematics and Computer Science
Abildgaard, O., Examiner
Jannerup, O. E., Examiner, Department of Electrical Engineering
DTU-Su Stipendium, Eksperiment
01/02/1993 → 04/09/1996
Award relations: Mechatronic approach in design and modelling of robotic manipulators
Project: PhD

Avancerede metoder i adaptiv regulering
Nørgård, P. M., PhD Student, Department of Automation
Ravn, O., Main Supervisor, Department of Electrical Engineering
Hansen, L. K., Supervisor, Department of Applied Mathematics and Computer Science
Poulsen, N. K., Supervisor, Department of Applied Mathematics and Computer Science
Jantzen, J., Examiner, Department of Automation
Wagner, C. H., Examiner, Department of Control and Engineering Design
DTU-Su Stipendium, Eksperiment
01/02/1993 → 20/09/1996
Award relations: Avancerede metoder i adaptiv regulering
Project: PhD

Intelligent Actuators and motion control of multivariable hydraulic systems
Andersen, T. O., PhD Student
Conrad, F., Main Supervisor, Department of Mechanical Engineering
Poulsen, N. K., Examiner
DTU-Su Stipendium, Eksperiment
01/02/1993 → 27/02/1997
Award relations: Intelligent Actuators and motion control of multivariable hydraulic systems
Project: PhD

Model Identification for Predictive Control and Optimization
Huusom, J. K., PhD Student, Department of Chemical and Biochemical Engineering
Jørgensen, S. B., Main Supervisor, Department of Chemical and Biochemical Engineering
Poulsen, N. K., Supervisor, Department of Informatics and Mathematical Modeling
Jørgensen, J. B., Examiner, Department of Chemical and Biochemical Engineering
Andersen, H. W., Examiner
Bombois, X., Examiner
DTU-lønnet stipendie
01/02/2005 → 24/11/2008
Award relations: Model Identification for Predictive Control and Optimization
Project: PhD

Model Predictive Control based on Stochastic Differential Equations - An Artificial Pancreas with Fast Insulin, Glucagon and Multiple Sensors
Hagdrup, M., PhD Student, Department of Applied Mathematics and Computer Science
Jørgensen, J. B., Main Supervisor, Department of Applied Mathematics and Computer Science
Madsen, H., Supervisor, Department of Applied Mathematics and Computer Science
Poulsen, B., Supervisor, Department of Applied Mathematics and Computer Science
Poulsen, N. K., Supervisor, Department of Applied Mathematics and Computer Science
Pedersen, M., Examiner, Department of Applied Mathematics and Computer Science
Cannon, M., Examiner
Scherer, C. W., Examiner
Institut stipendie (DTU)
01/09/2014 → 31/08/2018
Award relations: Model Predictive Control based on Stochastic Differential Equations - An Artificial Pancreas with Fast Insulin, Glucagon and Multiple Sensors
Project: PhD

Robotic Manipulation of Offshore Drilling Equipment
Choux, M., PhD Student, Department of Electrical Engineering
Blanke, M., Main Supervisor, Department of Electrical Engineering
Hovland, G., Supervisor
Poulsen, N. K., Examiner
Andersen, T. O., Examiner
Egeland, O., Examiner
Stipendie fra udlandet
01/02/2008 → 19/04/2012
Award relations: Robotic Manipulation of Offshore Drilling Equipment
Fault Diagnosis for Identification of Deviant Behavior
Jónsson, R. I., PhD Student, Department of Electrical Engineering
Blanke, M., Main Supervisor, Department of Electrical Engineering
Hejsgaard, S., Supervisor
Poulsen, N. K., Supervisor
Madsen, H., Examiner
Gustafsson, F., Examiner
Møl, R. M. D., Examiner
DTU, Samfinansiering
01/04/2007 → 22/06/2011
Award relations: Fault Diagnosis for Identification of Deviant Behavior
Project: PhD

Statistical modelling of tagging data from marine animals
Pedersen, M. W., PhD Student, Department of Informatics and Mathematical Modeling
Madsen, H., Main Supervisor, Department of Informatics and Mathematical Modeling
Thygesen, U. H., Supervisor, National Institute of Aquatic Resources
Poulsen, N. K., Examiner, Department of Informatics and Mathematical Modeling
Huse, G., Examiner
Zucchini, W., Examiner
DTU-lønnet stipendie
01/07/2007 → 02/02/2011
Award relations: Statistical modelling of tagging data from marine animals
Project: PhD

Estimation of Conditional densities for predictions in nonlinear stochastic processes - with applications to wind power systems
Tastu, J., PhD Student, Department of Informatics and Mathematical Modeling
Madsen, H., Main Supervisor, Department of Informatics and Mathematical Modeling
Pinson, P., Supervisor, Department of Informatics and Mathematical Modeling
Poulsen, N. K., Examiner, Department of Informatics and Mathematical Modeling
Kariniotakis, G., Examiner
Lindström, E., Examiner
DTU-lønnet stipendie
01/08/2007 → 12/12/2013
Award relations: Estimation of Conditional densities for predictions in nonlinear stochastic processes - with applications to wind power systems
Project: PhD

Navigationssystemer til mobile robotter
Andersen, J. C., PhD Student, Department of Electrical Engineering
Ravn, O., Main Supervisor, Department of Electrical Engineering
Andersen, N. A., Supervisor, Department of Electrical Engineering
Poulsen, N. K., Examiner, Department of Applied Mathematics and Computer Science
Christensen, H. I., Examiner
Henriksen, L., Examiner, Department of Automation
DTU-lønnet stipendie
15/03/2003 → 02/01/2007
Award relations: Navigationssystemer til mobile robotter
Project: PhD

Nonlinear identification and optimal control of fed-batch processes
Kristensen, N. R., PhD Student, Department of Chemical and Biochemical Engineering
Jørgensen, S. B., Main Supervisor, Department of Chemical and Biochemical Engineering
Madsen, H., Supervisor, Department of Applied Mathematics and Computer Science
Wiebe, L., Examiner
Holst, J., Examiner
Poulsen, N. K., Examiner, Department of Applied Mathematics and Computer Science
DTU-lønnet stipendie
01/08/1999 → 24/03/2003
Award relations: Nonlinear identification and optimal control of fed-batch processes
Project: PhD

Modeling and Forecasting for Optimal Participation of Renewable Energy in Deregulated Energy Markets
Jónsson, T., PhD Student, Department of Informatics and Mathematical Modeling
Pinson, P., Main Supervisor, Department of Informatics and Mathematical Modeling
Nielsen, T. S., Supervisor, Department of Informatics and Mathematical Modeling
Poulsen, N. K., Supervisor, Department of Informatics and Mathematical Modeling
Kulahci, M., Examiner, Department of Informatics and Mathematical Modeling
McSharry, P. E., Examiner
Meibom, P., Examiner
ErhvervsPhD-ordningen VTU
01/11/2008 → 24/08/2012
Award relations: Modeling and Forecasting for Optimal Participation of Renewable Energy in Deregulated Energy Markets
Project: PhD

Wind Turbine with Trailing Edge Flaps for Load Alleviation
Andersen, P. B., PhD Student, Department of Informatics and Mathematical Modeling
Poulsen, N. K., Main Supervisor, Department of Informatics and Mathematical Modeling
Bak, C., Supervisor
Buhl, T., Supervisor
Gaunaa, M., Supervisor
Knudsen, T., Examiner
Wedel-Heinen, J. J., Examiner
van Kulk, G., Examiner
Riso (Læn)
01/10/2006 → 30/06/2010
Award relations: Wind Turbine with Trailing Edge Flaps for Load Alleviation
Project: PhD

Power Management for Refrigeration Systems
Hovgaard, T. G., PhD Student, Department of Informatics and Mathematical Modeling
Jørgensen, J. B., Main Supervisor, Department of Informatics and Mathematical Modeling
Blanke, M., Supervisor, Department of Electrical Engineering
Larsen, L. F. S., Supervisor
Skovrup, M. J., Supervisor, Department of Energy Engineering
Poulsen, N. K., Examiner, Department of Informatics and Mathematical Modeling
Morari, M., Examiner
Melbak, T., Examiner, Department of Electrical Engineering
Mølbak, T., Examiner
ErhvervsPhD-ordningen VTU
01/04/2010 → 24/05/2013
Award relations: Power Management for Refrigeration Systems
Project: PhD

Economic MPC for Large and Distributed Energy Systems
Standardi, L., PhD Student
Jørgensen, J. B., Main Supervisor
Poulsen, N. K., Supervisor
Morales González, J. M., Examiner
Larsen, L. F. S., Examiner
Rossiter, J. A., Examiner
Eksternt finansieret virksomhed
01/11/2011 → 04/03/2015
Award relations: Economic MPC for Large and Distributed Energy Systems
Project: PhD

Stochastic Model Predictive Control with Applications in Smart Energy Systems
Sokoler, L. E., PhD Student
Jørgensen, J. B., Main Supervisor
Madsen, H., Supervisor
Poulsen, N. K., Supervisor
Knudsen, J. K. H., Examiner
Bemporad, A., Examiner
Zavala, V., Examiner
ErhvervsPhD-ordningen VTU
01/07/2012 → 31/03/2016
Award relations: Stochastic Model Predictive Control with Applications in Smart Energy Systems
Project: PhD

**Model Predictive Control algorithms for pen and pump insulin administration**
Boiroux, D., PhD Student, Department of Informatics and Mathematical Modeling
Jørgensen, J. B., Main Supervisor, Department of Informatics and Mathematical Modeling
Madsen, H., Supervisor, Department of Informatics and Mathematical Modeling
Poulsen, N. K., Supervisor, Department of Informatics and Mathematical Modeling
Serensen, M. P., Examiner, Department of Applied Mathematics and Computer Science
Knudsen, J. K. H., Examiner
del Re, L., Examiner
Forskningsrådsfinansiering
01/09/2009 → 22/11/2012
Award relations: Model Predictive Control algorithms for pen and pump insulin administration
Project: PhD

**Concurrent Aero-Servo-Elastic analysis and Design of wind turbines**
Mirzaei, M., PhD Student, Department of Informatics and Mathematical Modeling
Poulsen, N. K., Main Supervisor, Department of Informatics and Mathematical Modeling
Niemann, H. H., Supervisor, Department of Electrical Engineering
Jørgensen, J. B., Examiner, Department of Informatics and Mathematical Modeling
Bottasso, C. L., Examiner
Stoustrup, J., Examiner, Department of Applied Mathematics and Computer Science
Bottasso, C. L., Examiner
DTU, Samfinansiering
15/08/2009 → 07/03/2013
Award relations: Concurrent Aero-Servo-Elastic analysis and Design of wind turbines
Project: PhD

**Numerical Methods for Reservoir Simulation and Optimization**
Capolei, A., PhD Student, Department of Informatics and Mathematical Modeling
Jørgensen, J. B., Main Supervisor, Department of Informatics and Mathematical Modeling
Poulsen, N. K., Examiner, Department of Informatics and Mathematical Modeling
Jansen, J. D., Examiner
Knudsen, J. K. H., Examiner
Institut stipendie (DTU)
01/05/2010 → 25/04/2014
Award relations: Numerical Methods for Reservoir Simulation and Optimization
Project: PhD

**Demand Side Optimization via Direct Load Control in Smart Grids**
Costanzo, G. T., PhD Student, Department of Electrical Engineering
Bindner, H. W., Main Supervisor, Department of Electrical Engineering
Poulsen, N. K., Examiner
Lehnhoff, S., Examiner
Palensky, P., Examiner
Institut, samfinansiering
01/03/2012 → 09/12/2015
Award relations: Demand Side Optimization via Direct Load Control in Smart Grids
Project: PhD

**Model Predictive Control for Smart Energy Systems**
Halvgaard, R. F., PhD Student
Jørgensen, J. B., Main Supervisor
Madsen, H., Supervisor
Poulsen, N. K., Supervisor
Bindner, H. W., Examiner
Chmielewski, D. J., Examiner
Jones, C. N., Examiner
Institut stipendie (DTU)
01/11/2010 → 25/04/2014
Award relations: Model Predictive Control for Smart Energy Systems
Project: PhD

Enhanced Subsea Acoustically Aided Inertial Navigation
Jørgensen, M. J., PhD Student
Poulsen, N. K., Main Supervisor
Larsen, M. B., Supervisor
Møller, J. K., Examiner
la Cour-Harbo, A., Examiner
Pascoal, A. M., Examiner
Institut, samfinansiering
15/12/2011 → 24/02/2016
Award relations: Enhanced Subsea Acoustically Aided Inertial Navigation
Project: PhD

Optimization Algorithms for Experimental Design, Parameter Estimation, and Control of Dynamic Systems
Frison, G., PhD Student
Jørgensen, J. B., Main Supervisor
Poulsen, N. K., Supervisor
Engsig-Karup, A. P., Examiner
Axehill, D., Examiner
Ferreau, H. J., Examiner
Institut stipendie (DTU)
01/10/2012 → 20/04/2016
Award relations: Optimization Algorithms for Experimental Design, Parameter Estimation, and Control of Dynamic Systems
Project: PhD

Data Assimilation in Marine Modelling
Frydendall, J., PhD Student, Department of Informatics and Mathematical Modeling
Madsen, H., Main Supervisor, Department of Informatics and Mathematical Modeling
Sørensen, J. V. T., Supervisor, Department of Informatics and Mathematical Modeling
Poulsen, N. K., Examiner, Department of Informatics and Mathematical Modeling
Carstensen, N. J., Examiner
Heemink, A. W., Examiner
1/3 DTU-stip, 2/3 FUR/andet
01/03/2006 → 25/11/2009
Award relations: Data Assimilation in Marine Modelling
Project: PhD

Model-based predictive control of wind turbines
Henriksen, L. C., PhD Student, Department of Informatics and Mathematical Modeling
Poulsen, N. K., Main Supervisor, Department of Informatics and Mathematical Modeling
Hansen, M. H., Supervisor
Jørgensen, J. B., Examiner, Department of Informatics and Mathematical Modeling
Engelen, T. G. V., Examiner
Per, B., Examiner
Institut/centerfinansieret
15/05/2007 → 02/03/2011
Award relations: Model-based predictive control of wind turbines
Project: PhD

Adaptive Trailing Edge Flap, control for enhanced load alleviation
Bergami, L., PhD Student, Risø National Laboratory for Sustainable Energy
Gaunaa, M., Main Supervisor, Department of Energy Engineering
Buhl, T., Supervisor, Department of Solid Mechanics
Poulsen, N. K., Supervisor, Department of Informatics and Mathematical Modeling
Mikkelsen, R. F., Examiner, Department of Energy Engineering
Bossanyi, E., Examiner
Robust adaptive control system design for aerospace applications.

Hansen, A. D., PhD Student, Department of Wind Energy
Poulsen, N. K., Main Supervisor, Department of Applied Mathematics and Computer Science
Colding-Jørgensen, M., Supervisor
Mosekilde, E., Supervisor, Department of Physics
Knudsen, C., Examiner, Department of Physics
Bakker, B. M., Examiner
Sørensen, P. G., Examiner

Award relations: Robust adaptive control system design for aerospace applications.

Project: PhD

BIPS - None Touchable Inspections of Industrial Processes and Systems

Traditional ultrasound inspections require physical contact between the piezo-electric sound generator and the product or item to be investigated. Good contact is achieved by smearing oil onto the item which provides a good impedance match. In many potential new applications of ultrasound, physical contact is not desirable between the ultrasound generator/detector and the item to be inspected. This is the case in inspection at assembly lines, where the high speed of production do not allow cumbersome smearing and placement of an ultrasound generator/receiver onto the products on the line. However, in this project non contact ultrasound inspections are suggested to be accomplished using lasers. A powerful laser pulse is directed onto an item which generates a sound wave propagating through the item and is reflected from possible hidden defects. On return to the surface the wave is detected by laser beams who's interference patterns register the movement of the surface. The physical laser system is developed at Risø and FORCE Institute. The contribution to this project from IMM concerns mathematical modelling as an add to design and optimize a non touchable inspection system. This include modelling the generation of ultra sound through rapid laser heating from short pulses and wave propagation. Feedback control and steering of a production line with a non touchable inspection system implemented will be modelled and theoretically investigated.

Sørensen, M. P., Project Manager, Department of Informatics and Mathematical Modeling
Poulsen, N. K., Project Participant, Department of Informatics and Mathematical Modeling
Halkjær, S., Project Participant, Department of Informatics and Mathematical Modeling
Sevel, T., Project Participant, FORCE Technology
Lynov, J., Project Participant


Project: Research

Measurement of short-circuit capacity

The short-circuit capacity in the electric transmission and distribution system is important when connecting equipment to the network. In the transmission system, this could for example be connection of HVDC lines or very big consumers, and at lower voltage levels it could be minor power stations or other consumers. The short-circuit impedance is dependent on
the actual configuration of the network, and of the consumption. This investigation concerns establishing methods for measuring the short-circuit impedance from naturally occurring variations in voltage and current. In particular two cases, where the measurements are presently requested are investigated. The first case is about the 400 kV bus in Bjaeverskov, where the short-circuit capacity should be known before start of the HVDC line to Germany. The second case is a measurement on the 132 kV bus in Hove, where a pronounced consumer is connected, and the problem is voltage fluctuations, for which reason the impedance measurement is combined with a flicker measurement. In the project, two pc-based measurement systems are developed. The first one with the sampling rate locked to the power frequency, and the second one with constant sampling rate. In the frequency locked system, the naturally occurring variations in voltage and current are collected and used as basis for a statistical analysis and an estimation of the short-circuit impedance. In the system with constant frequency data acquisition, the method includes an algorithm for detection of significant events in the variation of voltage and current.

Nielsen, A. H., Project Manager, Department of Electric Power Engineering
Pedersen, K. O. H., Project Participant, Department of Electric Power Engineering
Poulsen, N. K., Project Participant, Department of Informatics and Mathematical Modeling

01/01/1996 → …

Project: Research

Adaptive control of a cutting process.

This activity concerns development of a nonlinear adaptive controller for a cutting process. The objective is to control the feed rate such that it is optimized without exceeding the permitted maximum torque acting on the tool. Most control systems currently available are simple and follow conservative strategies. In the current project we pursue various nonlinear adaptive control strategies for high performance control of the process. The controllers are designed to perform well for arbitrary combinations of material, type of tool, tool wear, depth of cut, and tool speed. The project is carried out in collaboration with Division of Manufacturing Engineering, Luleå University of Technology. This division has at its disposal a machining center with modified control hardware which is used for practical experiments. A nonlinear adaptive controller has been designed and various tests and fine tunings have been carried out. Practical experiments have demonstrated a promising performance for cutting in aluminum. In the forthcoming year we will explore the performance of the controller for other tools and materials.

Poulsen, N. K., Project Manager, Department of Informatics and Mathematical Modeling, CICT
Nargård, P. M., Project Participant, Department of Informatics and Mathematical Modeling, CICT
Ravn, O., Project Participant, Department of Automation
Bäckström, M., Project Participant, Luleå University of Technology

05/12/1996 → 05/12/1997

Collaborators: Luleå University of Technology

Project: Research

Adaptive Extremum control.

Ph.D. project. Ma Xin. The main idea in this project is to maximize some performance criteria by using adaptive control methods. The purpose of the controller design is to increase the efficiency of some processes. The extremum control is related to optimization techniques. A wind turbine is taken as an example for applying adaptive extremum control. In order to design a high performance control system, a detailed model of dynamic behaviour of the wind turbine is needed. Such a model can be achieved from two approaches: theoretical method and identification techniques. In this year the nonlinear theoretical model is established by using simulink, the system is modelled from known physics interpretations. Some control methods require the knowledge of wind speed, but it is impossible to measure the effective wind speed on the rotor plane. Therefore estimation of wind speed on the rotor plane is considered by using the wind turbine as wind measuring device. Several estimation methods are investigated.

Poulsen, N. K., Project Manager, Department of Informatics and Mathematical Modeling, Computer Science and Engineering
Ma, X., Project Participant, Department of Informatics and Mathematical Modeling, Computer Science and Engineering
Bindner, H., Project Participant

01/01/1996 → …

Project: Research

Delta-domain predictive control and identification for control.

Traditionally, discrete-time sampled-data systems are represented using shift-operator parametrizations. Such parametrizations are not suitable at fast sampling rates. An alternative parametrization using the so-called delta-operator is examined. It is shown how to maintain a close correspondence to continuous-time when sampling a system described in continuous-time by stochastic differential equations. A new prediction method is developed. It is based on ideas from continuous-time but derived from discrete-time delta-operator models. It is shown to include the optimal minimum-variance predictor as a special case and to have a well-defined continuous-time limit. By means of this new prediction method a unified framework for discrete-time and continuous-time predictive control algorithms is developed. This contains a continuous-time like discrete-time predictive controller which is insensitive to the choice of sampling period and has a well-defined limit in the continuous-time case. Also more conventional discrete-time predictive control methods may be described within the unified approach. The predictive control algorithms are extended to frequency weighted criterion functions. Also a state-space approach is described which extends straightforwardly to the multi-variable case. Finally,
aspects on the connection between system identification and control design are discussed. Several approaches to improve this interconnection have been proposed. The frequency-distribution of the estimation error with low-complexity models is treated and proves to be important for the development of control-relevant prefilters in estimation. Iterative approaches are presented, both using standard estimation methods with prefiltering and non-standard control-relevant estimation methods. New combined adaptive/iterative techniques are proposed.

Poulsen, N. K., Project Manager, Department of Informatics and Mathematical Modeling

Robust adaptive control
The goal in this project is to investigate and develop robust identification methods and adaptive controllers. The practical application is related to steering of ships (autopilots). Adaptive control is interesting in connection to ships, because these strategies are able to handle timevarying systems operating under unpredictable situations. In the period there has been focussed on model reduction in order to obtain resonable models suitable for control design. In the project there has been developed and investigated methods for designingpredictive controllers, which in the design procedure take the restriction into account. classical systemidentification is based on the models ability to predict one step a head. This ability is not necessarily connected to the control objective and methods for connecting control and systemidentification has been investigated.

Poulsen, N. K., Project Manager, Department of Informatics and Mathematical Modeling
Hansen, A. D., Project Participant, Department of Informatics and Mathematical Modeling

Dissipative methods
Project nr. 1219 Ph.D project. Uffe Hoegsbro Thygesen Control systems are often based on a mathematical model for the control object in terms of ordinary differential equations. There is always some uncertainty in such a model which may be modelled in terms of unknown system components (perturbations), uncertain parameters, and stochastic disturbances. A powerful framework for addressing the unknown system components builds on Jan C. Willem's theory of dissipation. Here one starts out with establishing quantities that the single component cannot produce, for instance energy. Then one investigates how these properties constraint the dynamical behaviour of the component. In a final step one is then able to give qualitative statements about the overall system. In this project we investigate the application of dissipation theory to robust (or worst-case) control. To this end we investigate system components which possess several properties of dissipation. Furthermore we consider adaptive control problems in which we seek controllers which are able to make the control object dissipative even when parameter uncertainty is present. Finally we develop a framework of dissipation applicable to systems in which stochastic disturbances also are present.

Poulsen, N. K., Project Manager, Department of Informatics and Mathematical Modeling
Thygesen, U. H., Project Participant, Department of Informatics and Mathematical Modeling

European Consortium for Mathematics in Industry (ECMI)
The goal of ECMI is to promote the interaction between universities and research groups in industry. The aims of ECMI are to promote the use of mathematical models in industry, to educate industrial mathematicians to meet the growing demand for such experts and finally to operate on a European scale. Activities comprises: Attracting EU funding for post docs and research in industrial mathematics, student exchange through ERASMUS, organizing ECMI modelling weeks, biannual conferences, European Study Groups for Industry (ESGI), and others.

Sørensen, M. P., Project Manager, Department of Informatics and Mathematical Modeling
Poulsen, N. K., Project Participant, Department of Informatics and Mathematical Modeling

Modelling and control of flexible robot
The project deals with the modelling and control of flexible robot arms with special reference to be able to increase the payload/own weight ratio of manipulators. It is of vital importance to improve this ratio in the endeavour to improve the skills and the efficiency of future robots. The mechatronic approach in robotics is tested in a design case study of a pick and place 2 DOF SCARA robot as the restrictive constraint in the mechanical design that the links have to be rigid is relaxed. To maintain a good link tip position accuracy the relaxing of the constraint necessitate improved knowledge in the
remaining involved disciplines in the integrated design in order to avoid that vibrations induced in the robot link have
destructive effect on the tip positioning. A brief introduction to the modelling of distributed parameter systems is
subsequently given before the theory is applied in modelling a flexible robot arm. A number of link models are derived. The
first two models presented describes in-plane transverse vibrations in a free rotating flexible robot link. (modal
representation and finite element modelling). In some applications of manipulators they interact with the environment
which affect the dynamics of a flexible link. This fact resulted in the derivation of three models of a flexible link used in tip
force control. The extended knowledge of the behaviour of a working flexible robot link gained is used on the case study
manipulator in a passive non-ad-hoc rigid robot design application and in an active flexible robot design application. Out-
of-plane link vibrations are treated as well in the thesis as they in most applications will be excited too. In order to be
able to damp the out-of-plane transverse vibrations a lightweight distributed piezoelectric actuator is introduced which acts
as an active artificial stiffening in the particular direction.

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