Carbon dioxide not suitable for extinguishment of smouldering silo fires: static electricity may cause silo explosion

Smouldering fires in wood pellet silos are not uncommon. The fires are often difficult to deal with and extinguishment is a lengthy process. Injection of inert gasses to prevent oxygen from reaching the smouldering fire zone and suppress combustion is a new firefighting strategy. This article argues that injection of inert carbon dioxide into the silo headspace is unsafe. Carbon dioxide is generally available as a liquid under high pressure. When discharged, small particles of dry ice are formed. The rapid flow of particles can generate considerable amounts of static electricity, which can act as a source of ignition if ignitable pyrolysis gasses are present. This article discusses a serious wood pellet smouldering fire and silo explosion in Norway in 2010, which took place when firefighters discharged portable CO2 fire extinguishers into the headspace. The attempt to suppress the fire may have ignited pyrolysis gasses. The article examines selected guidelines, standards, popular wood pellet handbooks and other literature and argues that the electrostatic hazard is widely underappreciated. In the past, major explosions have been attributed to electrostatic ignition of flammable vapours during the release of CO2 for fire prevention purposes. There is evidence to suggest that those early lessons learned have at least partly passed out of sight.
Dangers of using CO₂ to quench wood pellet silo fires

General information
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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Statistics and Data Analysis, Industrial Fire Prevention LLC
Authors: Hedlund, F. H. (Intern), Nichols, J. (Ekstern)
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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.

**General information**
State: Published
Organisations: Department of Electrical Engineering, Automation and Control, Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Sekunda, A. K. (Intern), Niemann, H. H. (Intern), Poulsen, N. K. (Intern)
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- Scopus rating (2016): CiteScore 2.04 SJR 0.886 SNIP 1.102
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- Scopus rating (2014): SJR 1.245 SNIP 1.357 CiteScore 1.98
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- Scopus rating (2013): SJR 0.945 SNIP 1.256 CiteScore 2.07
- ISI indexed (2013): ISI indexed yes
- Web of Science (2013): Indexed yes
- BFI (2012): BFI-level 1
- Scopus rating (2012): SJR 0.843 SNIP 1.286 CiteScore 1.84
- ISI indexed (2012): ISI indexed yes
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- Scopus rating (2011): SJR 0.889 SNIP 0.988 CiteScore 1.45
- ISI indexed (2011): ISI indexed yes
- BFI (2010): BFI-level 1
- Scopus rating (2010): SJR 0.871 SNIP 1.217
- BFI (2009): BFI-level 1
- Scopus rating (2009): SJR 1.39 SNIP 1.578
- BFI (2008): BFI-level 2
- Scopus rating (2008): SJR 1.374 SNIP 1.89
- Scopus rating (2007): SJR 1.049 SNIP 1.59
- Scopus rating (2006): SJR 0.716 SNIP 1.047
- Scopus rating (2005): SJR 0.657 SNIP 1.217
- Scopus rating (2004): SJR 0.744 SNIP 1.105
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Do Not Release Carbon Dioxide If Flammable Vapors Are Present – Static Electricity May Lead To Explosion

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Authors: Hedlund, F. H. (Intern)
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Publication: Communication › Internet publication – Annual report year: 2018

Dynamic Allocation or Diversification: A Regime-Based Approach to Multiple Assets
This article investigates whether regime-based asset allocation can effectively respond to changes in financial regimes at the portfolio level in an effort to provide better long-term results when compared to a static 60/40 benchmark. The potential benefit from taking large positions in a few assets at a time comes at the cost of reduced diversification. The authors analyze this trade-off in a multi-asset universe with great potential for static diversification. The regime-based approach is centered around a regime-switching model with time-varying parameters that can match financial markets’ behavior and a new, more intuitive way of inferring the hidden market regimes. The empirical results show that regime-based asset allocation is profitable, even when compared to a diversified benchmark portfolio. The results are robust because they are based on available market data with no assumptions about forecasting skills.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Sampension, Lund University
Authors: Nystrup, P. (Intern), Hansen, B. W. (Ekstern), Larsen, H. O. (Ekstern), Madsen, H. (Intern), Lindström, E. (Ekstern)
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Kuldioxid er uegnet til kvælning af glødebrande

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Authors: Hedlund, F. H. (Intern)  
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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.
Scattering of flexural waves in Euler-Bernoulli beams by short-range potentials: Paper

Time-harmonic flexural waves on a beam and on two elastically coupled beams with short-range localized imperfections in the mass distribution and in the position dependant coupling are considered. Thus scattering of an incident wave solution to the Euler-Bernoulli equation by a Dirac delta function and its derivative up to order three is studied, and the possible physical interpretations are outlined. Reflected, transmitted and evanescent waves exist, and their scattering data are determined. For δ(x) and δ'(x), the scattering problem is solved by standard integration. For δ''(x) and δ'''(x), the standard integration procedure does not work and solutions are obtained by regularization. In the latter case the scatterer is in general nontransparent and only partially penetrable at discrete resonances. The first few of these as well as their scattering data are determined numerically.
Silo response - The dangers of using carbon dioxide to quench silo fires

General information
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Wind Power Forecasting Based on Echo State Networks and Long Short-Term Memory
Wind power generation has presented an important development around the world. However, its integration into electrical systems presents numerous challenges due to the variable nature of the wind. Therefore, to maintain an economical and reliable electricity supply, it is necessary to accurately predict wind generation. The Wind Power Prediction Tool (WPPT) has been proposed to solve this task using the power curve associated with a wind farm. Recurrent Neural Networks (RNNs) model complex non-linear relationships without requiring explicit mathematical expressions that relate the variables involved. In particular, two types of RNN, Long Short-Term Memory (LSTM) and Echo State Network (ESN),
have shown good results in time series forecasting. In this work, we present an LSTM+ESN architecture that combines the characteristics of both networks. An architecture similar to an ESN is proposed, but using LSTM blocks as units in the hidden layer. The training process of this network has two key stages: (i) the hidden layer is trained with a descending gradient method online using one epoch; (ii) the output layer is adjusted with a regularized regression. In particular, the case is proposed where Step (i) is used as a target for the input signal, in order to extract characteristics automatically as the autoencoder approach; and in the second stage (ii), a quantile regression is used in order to obtain a robust estimate of the expected target. The experimental results show that LSTM+ESN using the autoencoder and quantile regression outperforms the WPPT model in all global metrics used.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Universidad Tecnica Federico Santa Maria
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BFI (2015): BFI-level 2
Scopus rating (2015): SJR 0.804 SNIP 1.416 CiteScore 2.87
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 0.87 SNIP 1.601 CiteScore 2.66
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.632 SNIP 1.345 CiteScore 2.29
ISI indexed (2013): ISI indexed yes
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Scopus rating (2012): SJR 0.874 SNIP 1.54 CiteScore 2.46
ISI indexed (2012): ISI indexed yes
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Online short-term forecast of greenhouse heat load using a weather forecast service

In some district heating systems, greenhouses represent a significant share of the total load, and can lead to operational challenges. Short term load forecast of such consumers has a strong potential to contribute to the improvement of the overall system efficiency. This work investigates the performance of recursive least squares for predicting the heat load of individual greenhouses in an online manner. Predictor inputs (weekly curves terms and weather forecast inputs) are selected in an automated manner using a forward selection approach. Historical load measurements from 5 Danish greenhouses with different operational characteristics were used, together with weather measurements and a weather forecast service. It was found that these predictors of reduced complexity and computational load performed well at capturing recurring load profiles, but not fast frequency random changes. Overall, the root mean square error of the prediction was within 8–20% of the peak load for the set of consumers over the 8 months period considered.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Aalborg University
Authors: Vogler-Finck, P. J. (Ekstern), Bacher, P. (Intern), Madsen, H. (Intern)
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BFI (2015): BFI-level 2
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Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
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BFI (2012): BFI-level 1
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ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 2.473 SNIP 2.84 CiteScore 5.5
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
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General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, University of Malta, Galea Curmi Engineering Services Ltd.
Authors: Caruana, C. (Ekstern), Yousif, C. (Ekstern), Bacher, P. (Intern), Buhagiar, S. (Ekstern), Grima, C. (Ekstern)
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Determination of thermal characteristics of standard and improved hollow concrete blocks using different measurement techniques
The lighter weight, improved thermal properties and better acoustic insulation of hollow-core concrete blocks are few of the characteristics that one encounters when comparing them to traditional Maltese globigerina limestone solid blocks. As a result, hollow concrete blocks have recently been in greater demand. However, their transmittance, or U-value, is still quite high and does not meet the minimum energy requirements for constructing new buildings. This paper is focused on the investigation of the thermal properties of a new building block, developed as part of a nationally-funded research project ThermHCB, with the aim of improving the U-value of such blocks without changing their compressive strength, physical dimensions or manufacturing process. Measurement techniques were applied to obtain comparative values of the thermal transmittance for standard and improved HCBs, using different EN and draft standards. Compressive testing was carried out concurrently in order to ensure that the minimum benchmark compressive strength was reached. The comparison between these results provides information on the reliability of the methodologies used to determine the thermal properties of building elements in-situ, without having to conduct such tests in a laboratory hot box setup.

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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, University of Malta, Galea Curmi Engineering Services Ltd.
Authors: Caruana, C. (Ekstern), Yousif, C. (Ekstern), Bacher, P. (Intern), Buhagiar, S. (Ekstern), Grima, C. (Ekstern)
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General information
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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, University of Malta, Galea Curmi Engineering Services Ltd.
Authors: Caruana, C. (Ekstern), Yousif, C. (Ekstern), Bacher, P. (Intern), Buhagiar, S. (Ekstern), Grima, C. (Ekstern)
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Determination of thermal characteristics of standard and improved hollow concrete blocks using different measurement techniques
The lighter weight, improved thermal properties and better acoustic insulation of hollow-core concrete blocks are few of the characteristics that one encounters when comparing them to traditional Maltese globigerina limestone solid blocks. As a result, hollow concrete blocks have recently been in greater demand. However, their transmittance, or U-value, is still quite high and does not meet the minimum energy requirements for constructing new buildings. This paper is focused on the investigation of the thermal properties of a new building block, developed as part of a nationally-funded research project ThermHCB, with the aim of improving the U-value of such blocks without changing their compressive strength, physical dimensions or manufacturing process. Measurement techniques were applied to obtain comparative values of the thermal transmittance for standard and improved HCBs, using different EN and draft standards. Compressive testing was carried out concurrently in order to ensure that the minimum benchmark compressive strength was reached. The comparison between these results provides information on the reliability of the methodologies used to determine the thermal properties of building elements in-situ, without having to conduct such tests in a laboratory hot box setup.
Evaluation of pharmacokinetic model designs for subcutaneous infusion of insulin aspart

Effective mathematical modelling of continuous subcutaneous infusion pharmacokinetics should aid understanding and control in insulin therapy. Thorough analysis of candidate model performance is important for selecting the appropriate models. Eight candidate models for insulin pharmacokinetics included a range of modelled behaviours, parameters and complexity. The models were compared using clinical data from subjects with type 1 diabetes with continuous subcutaneous insulin infusion. Performance of the models was compared through several analyses: $R^2$ for goodness of fit; the Akaike Information Criterion; a bootstrap analysis for practical identifiability; a simulation exercise for predictability. The simplest model fit poorly to the data ($R^2 = 0.53$), had the highest Akaike score, and worst prediction. Goodness of fit improved with increasing model complexity ($R^2 = 0.85–0.92$) but Akaike scores were similar for these models. Complexity increased practical non-identifiability, where small changes in the dataset caused large variation (CV > 10%) in identified parameters in the most complex models. Best prediction was achieved in a relatively simple model. Some model complexity was necessary to achieve good data fit but further complexity introduced practical non-identifiability and worsened prediction capability. The best model used two linear subcutaneous compartments, an interstitial and plasma compartment, and two identified variables for interstitial clearance and subcutaneous transfer rate. This model had optimal performance trade-off with reasonable fit ($R^2 = 0.85$) and parameterisation, and best prediction and practical identifiability (CV < 2%).
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.

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
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Publication: Research › Patent – Annual report year: 2017
Inhomogeneous Markov Models for Describing Driving Patterns

It has been predicted that electric vehicles will play a crucial role in incorporating a large renewable component in the energy sector. If electric vehicles are integrated in a naive way, they may exacerbate issues related to peak demand and transmission capacity limits while not reducing polluting emissions. Optimizing the charging of electric vehicles is paramount for their successful integration. This paper presents a model to describe the driving patterns of electric vehicles in order to provide primary input information to any mathematical programming model for optimal charging. Specifically, an inhomogeneous Markov model that captures the diurnal variation in the use of a vehicle is presented. The model is defined by the time-varying probabilities of starting and ending a trip, and is justified due to the uncertainty associated with the use of the vehicle. The model is fitted to data collected from the actual utilization of a vehicle. Inhomogeneous Markov models imply a large number of parameters. The number of parameters in the proposed model is reduced using B-splines.

A combined experimental and simulation based approach to model the flow-front dynamics in the vacuum assisted resin transfer moulding process.

With more emphasis on the use of green energy, the size of the turbines and blades in the wind turbines is continuously increasing. With increasing blade size, the casting process becomes more complicated and the risk of faults increases.
Production of such blades, made of fibre reinforced polymer composites, without the possibility of visual inspection of the infusion process calls for a sensor system (possibly virtual) for monitoring the process. This paper proposes a two-step modelling methodology to identify the parameters related to the flow-front that are essential for determining the current state of infusion process.

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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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BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.194 SNIP 2.091 CiteScore 3.05
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.

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Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems
Authors: Mahmoudi, Z. (Intern), Poulsen, N. K. (Intern), Madsen, H. (Intern), Jørgensen, J. B. (Intern)
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A deep learning approach to adherence detection for type 2 diabetics

Diabetes has become one of the biggest health problems in the world. In this context, adherence to insulin treatment is essential in order to avoid life-threatening complications. In this pilot study, a novel adherence detection algorithm using Deep Learning (DL) approaches was developed for type 2 diabetes (T2D) patients, based on simulated Continuous Glucose Monitoring (CGM) signals. A large and diverse amount of CGM signals were simulated for T2D patients using a T2D adapted version of the Medtronic Virtual Patient (MVP) model for T1D. By using these signals, different classification algorithms were compared using a comprehensive grid search. We contrast a standard logistic regression baseline to Multi-Layer Perceptrons (MLPs) and Convolutional Neural Networks (CNNs). The best classification performance with an average accuracy of 77.5% was achieved with CNN. Hence, this indicates the potential of DL, when considering adherence detection systems for T2D patients.

General information
State: Published
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A Dynamic Characterization of Energy Flexibility

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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Universidade Nova de Lisboa
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Aggregation model for curtailable generation and sheddable loads
This study shows modelling developed during the first year of the SmartNet project. In particular, it presents a mathematical model for aggregation of curtailable generation and sheddable loads. The model determines the quantity and the cost of the flexibility provided by the flexible resources based on their physical and dynamic behaviours. The model also proposes a bidding strategy in order to translate the aggregated behaviour into market bids.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, SINTEF, University of Strathclyde
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Bibliographical note
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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.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Copenhagen University Hospital
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BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.871 SNIP 0.971 CiteScore 1.84
BFI (2013): BFI-level 1
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An Aerial Robot for Rice Farm Quality Inspection With Type-2 Fuzzy Neural Networks Tuned by Particle Swarm Optimization-Sliding Mode Control Hybrid Algorithm

Agricultural robots, or agrobots, have been increasingly adopted in every aspect of farming from surveillance to fruit harvesting in order to improve the overall productivity over the last few decades. Motivated by compelling growth of agricultural robots in modern farms, in this work, an autonomous quality inspection over rice farms is proposed by employing quadcopters. Real-time control of these vehicles, however, is still challenging as they exhibit highly nonlinear behavior especially for agile maneuvers. What is more, these vehicles have to operate under uncertain working conditions such as wind and gust disturbances as well as positioning errors caused by inertial measurement units and global positioning system. To handle these difficulties, as a model-free and learning control algorithm, type-2 fuzzy neural networks (T2-FNNs) are designed for the control of quadcopter. The novel particle swarm optimization-sliding mode control (PSO-SMC) theory-based hybrid algorithm is proposed for the training of T2-FNNs. In particular, continuous version of PSO is adopted for the identification of the antecedent part of T2-FNNs while SMC-based update rules are utilized for online learning of the consequent part during control. In the virtual environment, the quadcopter is expected to perform an autonomous flight including agile maneuvers such as steep turning and sudden altitude changes over a rice terrace farm in Longsheng, China. The simulation results for T2-FNNs are compared with the outcome of conventional proportional-derivative (PD) controllers for different case studies. The results show that our method decreases trajectory tracking integral squared error by %26 over PD controllers in the ideal case, while this ratio goes up to %95 under uncertain working conditions.
Analysis of trait-based models in marine ecosystems.
The overarching theme for this thesis is spatial and temporal variations in ecosystems. The focus is on describing mechanisms that are responsible for generating the spatial and temporal patterns. The thesis contains two separate projects, each exploring a possible mechanism for pattern formation. In both projects, the model formulations result in partial integro-differential equations. The first project in the thesis considers temporal patterns in a size structured population. Size structure is relevant for species that goes through significant changes through their lifetime. The population’s response to regular temporal variations in the environment is investigated by introducing a periodic forcing in the system. This can for instance represent seasonal changes. The effect of an imposed forcing is explored both when the underlying unforced system has a stable equilibrium and when it has stable oscillatory dynamics. The numerical solutions show regular cycles where the period is equal to, or an integer multiple of, the forcing period and where the population can have one or more pulses of reproduction in each cycle. Additionally, the numerical results indicate quasi-periodic or chaotic solutions, period doubling bifurcations and coexisting attractors. The bifurcation structure is similar to results for comparable unstructured population models in the literature. This indicates that size structure does not affect the response to periodic forcing. The next project in the thesis considers spatio-temporal pattern formation in a predator–prey system where animals move towards higher fitness. Reaction-diffusion systems have been used extensively to describe spatio-temporal patterns in a variety of systems. However, animals rarely move completely at random, as expressed by diffusion. This has lead to models with taxis terms, describing individuals moving in the direction of an attractant. An example is chemotaxis models, where bacteria are attracted to a chemical substance. From an evolutionary perspective, it is expected that animals act as to optimize their fitness. Based on this principle, a predator–prey system with fitness taxis and diffusion is proposed. Here, fitness taxis refer to animals moving towards higher values of fitness, and the specific growth rates of the populations are used as a measure of the fitness values. To determine the conditions for pattern formation, a linear stability analysis is conducted. The analysis reveals that the fitness taxis leads to mechanisms for pattern formation, which are based on the prey gathering together. It turns out, that in some cases the problem is not well-posed and an ultraviolet catastrophe occurs, i.e., perturbations with infinitely short wavelength grow infinitely fast. To prevent this, the population dynamics are revised with a spatial feeding kernel, that defines a spatial range wherein a predator consumes prey. A linear stability analysis for the revised system reveals the ultraviolet catastrophe is avoided and the basic mechanisms for pattern formation are unchanged. Numerical solutions to the revised system are computed to visualize the patterns. The solutions encompass stationary spatial patterns in addition to traveling waves, standing waves and irregular solutions that might be spatio-temporal chaos. The modeling approach of fitness taxis presents a general way to express movement and it is concluded that the model provides a useful framework for describing generic mechanisms for pattern formation.
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.

General information
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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
An Improved Direction of Gradient-type Method for Large Scale Unconstrained Optimization

In this paper, a new modification of diagonal-gradient-type method for large scale unconstrained optimization is proposed. We utilize information from the proceeding iteration and consider some corrections for the difference of iterates to improve the current Hessian approximation in diagonal form. Also, the global convergence, under mild conditions is established. Finally, we report some numerical results to show the efficiency of our proposed method.

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A Robust Statistical Model to Predict the Future Value of the Milk Production of Dairy Cows Using Herd Recording Data

The future value of an individual dairy cow depends greatly on its projected milk yield. In developed countries with developed dairy industry infrastructures, facilities exist to record individual cow production and reproduction outcomes consistently and accurately. Accurate prediction of the future value of a dairy cow requires further detailed knowledge of the costs associated with feed, management practices, production systems, and disease. Here, we present a method to predict the future value of the milk production of a dairy cow based on herd recording data only. The method consists of several steps to evaluate lifetime milk production and individual cow somatic cell counts and to finally predict the average production for each day that the cow is alive. Herd recording data from 610 Danish Holstein herds were used to train and test a model predicting milk production (including factors associated with milk yield, somatic cell count, and the survival of individual cows). All estimated parameters were either herd- or cow-specific. The model prediction deviated, on average, less than 0.5 kg from the future average milk production of dairy cows in multiple herds after adjusting for the effect of somatic cell count. We conclude that estimates of future average production can be used on a day-to-day basis to rank cows for culling, or can be implemented in simulation models of within-herd disease spread to make operational decisions, such as culling versus treatment. An advantage of the approach presented in this paper is that it requires no specific knowledge of disease status or any other information beyond herd recorded milk yields, somatic cell counts, and reproductive status.

General information

State: Published
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Number of pages: 9
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A Stochastic Method to Manage Delay and Missing Values for In-Situ Sensors in an Alternating Activated Sludge Process

In the alternating activated sludge process with rule-based control, online N-measurements are of great importance for maintaining good control. These measurements can be delayed due to sensor processing time, turbulence at the location in the aeration tank where the sensor is placed, etc. The measurements may also be temporarily unavailable because of recalibration, communication faults or other errors. Here we present a method that handles such delay and missing observations. The model is based on zero order hold stochastic differential equations which use binary signals for influent flow and aeration to determine the state of the alternating process. It also uses measured ammonium and nitrate concentrations, which are shifted to account for delay. The method is developed and tested with data from a WWTP located in Kolding, Denmark. Results indicate that even though the model is simple, the model residuals and parameters
are uncorrelated and the model predictions are 60% closer to the true values (measurements shifted to account for delay) than the delayed measurements are.

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State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Environmental Engineering, Urban Water Systems, Krüger A/S
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Biomass accident investigations – missed opportunities for learning and accident prevention
The past decade has seen a major increase in the production of energy from biomass. The growth has been mirrored in an increase of serious biomass related accidents involving fires, gas explosions, combustible dust explosions and the release of toxic gasses. There are indications that the number of bioenergy related accidents is growing faster than the energy production. This paper argues that biomass accidents, if properly investigated and lessons shared widely, provide ample opportunities for improving general hazard awareness and safety performance of the biomass industry. The paper examines selected serious accidents involving biogas and wood pellets in Denmark and argues that such opportunities for learning were missed because accident investigations were superficial, follow-up incomplete and information sharing absent. In one particularly distressing case, a facility saw a repeat accident, this time with fatal outcome, still without any learning taking place. The paper presents some information on other biomass accidents in Denmark, mostly involving biogas from anaerobic digestion. Details are lacking however, precisely because the accidents were insufficiently investigated and results not communicated. The biomass industry needs to pay more attention to safety. Utmost care should be taken to avoid so-called mediashifting i.e. that the resolution of a problem within one domain, the environmental,
creates a new problem in another, the workplace safety domain.

Biomass Supply Planning for Combined Heat and Power Plants using Stochastic Programming
During the last years, the consumption of biomass to produce power and heat has increased due to the new carbon neutral policies. Nowadays, many district heating systems operate their combined heat and power (CHP) plants using different types of biomass instead of fossil fuel, especially to produce heat. Since biomass is transported from the supplier to the consumption sites and the contracts with the suppliers are negotiated months in advance, the negotiation process involves many uncertainties from the energy producer's side. The demand for biomass is uncertain at the time of negotiation, and heat demand and electricity prices vary drastically during the planning period. Furthermore, the optimal operation of combined heat and power plants has to consider the existing synergies between the power and heating systems while always fulfilling the heat demand of the system. We propose a solution method using stochastic optimization to support the biomass supply planning for combined heat and power plants. Our two-phase approach combines mid-term decisions about biomass supply contracts with the short-term decisions regarding the optimal market participation of the producer to ensure profitability and feasibility. The risk of major deficits in biomass supply is reduced by including appropriate risk measures to the models. We present numerical results and an economic analysis based on a realistic test case.

Blygsamt övertryck fick spektakulära följder
För att minska besvärande skumning sattes en tank under "mycket blygsamt" övertryck. Plötsligt brast botten. Tanken för 30 meter upp i luften, föll ned och krossade en varubil. Olyckan visar att en stor gasvolym under lågt tryck innehåller en väsentlig mängd energi.
Comparison of Different Classification Algorithms for the Detection of User’s Interaction with Windows in Office Buildings

Occupant behavior in terms of interactions with windows and heating systems is seen as one of the main sources of discrepancy between predicted and measured heating, ventilation and air conditioning (HVAC) building energy consumption. Thus, this work analyzes the performance of several classification algorithms for detecting occupant’s interactions with windows, while taking the imbalanced properties of the available data set into account. The tested methods include support vector machines (SVM), random forests, and their combination with dynamic Bayesian networks (DBN). The results will show that random forests outperform all alternative approaches for identifying the window status in office buildings.

General information
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- Web of Science (2016): Indexed yes
- BFI (2015): BFI-level 1
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- BFI (2014): BFI-level 1
- Scopus rating (2014): SJR 0.433 SNIP 0.81 CiteScore 1.09
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- Scopus rating (2013): SJR 0.425 SNIP 0.785 CiteScore 1.02
- ISI indexed (2013): ISI indexed no
- Web of Science (2013): Indexed yes
- Scopus rating (2012): SJR 0.425 SNIP 0.563 CiteScore 1.08
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- Web of Science (2012): Indexed yes
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- Scopus rating (2010): SJR 0.433 SNIP 0.957
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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 feed 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.

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Authors: Petersen, L. N. (Intern), Poulsen, N. K. (Intern), Niemann, H. H. (Intern), Utzen, C. (Ekstern), Jørgensen, J. B. (Intern)
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Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.521 SNIP 2.735 CiteScore 3.92
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.507 SNIP 2.607 CiteScore 3.47
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Cross-Validation of a Glucose-Insulin-Glucagon Pharmacodynamics Model for Simulation using Data from Patients with Type 1 Diabetes

Background:
Currently, no consensus exists on a model describing endogenous glucose production (EGP) as a function of glucagon concentrations. Reliable simulations to determine the glucagon dose preventing or treating hypoglycemia or to tune a dual-hormone artificial pancreas control algorithm need a validated glucoregulatory model including the effect of glucagon.

Methods:
Eight type 1 diabetes (T1D) patients each received a subcutaneous (SC) bolus of insulin on four study days to induce mild hypoglycemia followed by a SC bolus of saline or 100, 200, or 300 µg of glucagon. Blood samples were analyzed for concentrations of glucagon, insulin, and glucose. We fitted pharmacokinetic (PK) models to insulin and glucagon data using maximum likelihood and maximum a posteriori estimation methods. Similarly, we fitted a pharmacodynamic (PD) model to glucose data. The PD model included multiplicative effects of insulin and glucagon on EGP. Bias and precision of PD model test fits were assessed by mean predictive error (MPE) and mean absolute predictive error (MAPE).

Results:
Assuming constant variables in a subject across nonoutlier visits and using thresholds of ±15% MPE and 20% MAPE, we accepted at least one and at most three PD model test fits in each of the seven subjects. Thus, we successfully validated the PD model by leave-one-out cross-validation in seven out of eight T1D patients.

Conclusions:
The PD model accurately simulates glucose excursions based on plasma insulin and glucagon concentrations. The reported PK/PD model including equations and fitted parameters allows for in silico experiments that may help improve diabetes treatment involving glucagon for prevention of hypoglycemia.
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.
Dynamic Asset Allocation - Identifying Regime Shifts in Financial Time Series to Build Robust Portfolios

Long-term investors can often bear the risk of outsized market movements or tail events more easily than the average investor; for bearing this risk, they hope to earn significant excess returns. Rebalancing periodically to a fixed benchmark allocation, however, is not the way to do this. In the presence of time-varying investment opportunities, portfolio weights should be adjusted as new information arrives to take advantage of favorable regimes and reduce potential drawdowns. This thesis contributes to a better understanding of financial markets' behavior in the form of a model-based framework for dynamic asset allocation. Regime-switching models can match financial markets' tendency to change their behavior abruptly and the phenomenon that the new behavior often persists for several periods after a change. Regime shifts lead to time-varying parameters and, in addition, the parameters within the regimes and the transition probabilities change over
time. Using recursive and adaptive estimation techniques to capture this, we are able to better reproduce the volatility persistence that dynamic asset allocation benefits from. With this approach it is sufficient to distinguish between two regimes in stock returns in order for it to be profitable to change asset allocation based solely on the inferred regimes, both in a single asset multiasset universe. We advocate the use of model predictive control for translating forecasts into a dynamic strategy and controlling drawdowns by solving a multi-period optimization problem. We implement this based on forecasts from a multivariate hidden Markov model with time-varying parameters. Our results show that a substantial amount of value can be added by adjusting the asset allocation to the current market conditions, rather than rebalancing periodically to a static benchmark. By proposing a practical approach to drawdown control, we demonstrate the theoretical link to dynamic asset allocation and the importance of identifying and acting on regime shifts in order to limit losses and build robust portfolios.

**Dynamic portfolio optimization across hidden market regimes**
Regime-based asset allocation has been shown to add value over rebalancing to static weights and, in particular, reduce potential drawdowns by reacting to changes in market conditions. The predominant approach in previous studies has been to specify in advance a static decision rule for changing the allocation based on the state of financial markets or the economy. In this article, model predictive control (MPC) is used to dynamically optimize a portfolio based on forecasts of the mean and variance of financial returns from a hidden Markov model with time-varying parameters. There are computational advantages to using MPC when estimates of future returns are updated every time a new observation becomes available, since the optimal control actions are reconsidered anyway. MPC outperforms a static decision rule for changing the allocation and realizes both a higher return and a significantly lower risk than a buy-and-hold investment in various major stock market indices. This is after accounting for transaction costs, with a one-day delay in the implementation of allocation changes, and with zero-interest cash as the only alternative to the stock indices. Imposing a trading penalty that reduces the number of trades is found to increase the robustness of the approach.
Dynamic Rearrangement of Cell States Detected by Systematic Screening of Sequential Anticancer Treatments

Signaling networks are nonlinear and complex, involving a large ensemble of dynamic interaction states that fluctuate in space and time. However, therapeutic strategies, such as combination chemotherapy, rarely consider the timing of drug perturbations. If we are to advance drug discovery for complex diseases, it will be essential to develop methods capable of identifying dynamic cellular responses to clinically relevant perturbations. Here, we present a Bayesian dose-response framework and the screening of an oncological drug matrix, comprising 10,000 drug combinations in melanoma and pancreatic cancer cell lines, from which we predict sequentially effective drug combinations. Approximately 23% of the tested combinations showed high-confidence sequential effects (either synergistic or antagonistic), demonstrating that cellular perturbations of many drug combinations have temporal aspects, which are currently both underutilized and poorly understood.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Center for Biological Sequence Analysis, Novo Nordisk Foundation Center for Biosustainability, Bacterial Synthetic Biology, University of Copenhagen, University of New South Wales
Dynamics of a railway vehicle on a laterally disturbed track

In this article a theoretical investigation of the dynamics of a railway bogie running on a tangent track with a periodic disturbance of the lateral track geometry is presented. The dynamics is computed for two values of the speed of the vehicle in combination with different values of the wavelength and amplitude of the disturbance. Depending on the combinations of the speed, the wavelength and the amplitude, straight line forward motion, different modes of symmetric or asymmetric periodic oscillations or aperiodic motions, which are presumably chaotic, are found. Statistical methods are applied for the investigation. In the case of sinusoidal oscillations they provide information about the phase shift between the different variables and the amplitudes of the oscillations. In the case of an aperiodic motion the statistical measures indicate some non-smooth transitions.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Christiansen, L. E. (Intern), True, H. (Intern)
Number of pages: 32
Pages: 1-32
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: Vehicle System Dynamics
ISSN (Print): 0042-3114
Economic MPC based on LPV model for thermostatically controlled loads

Rapid increase of the renewable energy share in electricity production requires optimization and flexibility of the power consumption side. Thermostatically controlled loads (TCLs) have a large potential for regulation service provision. Economic model predictive control (MPC) is an advanced control method which can be used to synchronize the power consumption with undispatchable renewable electricity production. Thermal behavior of TCLs can be described by linear models based on energy balance of the system. In some cases, parameters of the model may be time-varying. In this work, we present a modified economic MPC based on linear parameter-varying model. In particular, we provide an exact transformation from a standard economic MPC formulation to a linear program. We assume that the variables influencing the model parameters are known (predictable) for the prediction horizon of the controller. As a case study, we present...
control system that minimizes operational cost of swimming pool heating system, where parameters of the model depend on the weather forecast. Simulation results demonstrate that the proposed method is able to deal with this kind of systems.

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Scientific Computing, Technical University of Liberec, Novosibirsk State Technical University
Authors: Zemtsov, N. (Ekstern), Hlava, J. (Ekstern), Frantsuzova, G. (Ekstern), Madsen, H. (Intern), Junker, R. G. (Intern), Jørgensen, J. B. (Intern)
Number of pages: 5
Publication date: 2017

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ISBN (Print): 9781509010813
Main Research Area: Technical/natural sciences
Conference: 2017 International Siberian Conference on Control and Communications, Astana, Kazakhstan, 29/06/2017 - 29/06/2017
Economic model predictive control, Linear time-varying model, Smart energy grid, Thermostatically controlled loads
DOI: 10.1109/SIBCON.2017.7998560
Source: FindIt
Source-ID: 2372744332
Publication: Research - peer-review › Article in proceedings – Annual report year: 2017

**Effect of different oral oxytetracycline treatment regimes on selection of antimicrobial resistant coliforms in nursery pigs**

A major concern derived from using antimicrobials in pig production is the development of resistance. This study aimed to assess the impact of selected combinations of oral dose and duration of treatment with oxytetracycline (OTC) on selection of tetracycline resistant (TET-R) coliforms recovered from swine feces. The work encompassed two studies: 1) OTC 5 mg/kg and 20 mg/kg were administered to nursery pigs for 3 and 10 days, respectively, under controlled experimental conditions, and 2) 10 mg/kg, 20 mg/kg and 30 mg/kg OTC were given to a higher number of pigs for 6, 3 and 2 days, respectively, under field conditions. Statistical modeling was applied to analyze trends in the proportion of TET-R coliforms. In the experimental study, no statistical difference in proportion of TET-R coliforms was observed between treatments at the end of the trial (day 18) and compared to day 0. In the field study, treatment had a significant effect on the proportion of TET-R bacteria two days after the end of treatment (2dAT) with the regimes "low dose-six days" and "medium dose-three days" yielding the highest and lowest proportions of TET-R strains, respectively. No indication of co-selection for ampicillin- and sulphonamide-R bacteria was observed for any treatment at 2dAT. By the end of the nursery period, the proportion of TET-R bacteria was not significantly different between treatments and compared to day 0. Our results suggest that similar resistance levels might be obtained by using different treatment regimes regardless of the combinations of oral dose-duration of treatment.

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Office for Study Programmes and Student Affairs, University of Copenhagen, Danvet K/S
Authors: Fresno, A. H. (Ekstern), Zachariasen, C. (Ekstern), Norholm, N. (Ekstern), Holm, A. (Ekstern), Christiansen, L. E. (Intern), Olsen, J. E. (Ekstern)
Number of pages: 7
Pages: 1-7
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Main Research Area: Technical/natural sciences

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Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
Effect of tetracycline dose and treatment-mode on selection of resistant coliform bacteria in nursery pigs
This study describes results of a randomized clinical trial investigating the effect of oxytetracycline treatment dose and mode of administration on selection of antibiotic resistant coliform bacteria in fecal samples from nursery pigs. Nursery pigs (pigs of 4-7 weeks of age) were treated with oxytetracycline against Lawsonia intracellularis induced diarrhea in five pig herds. Each group was randomly allocated to one of five treatment groups: oral flock treatment with (i) high (20 mg/kg), (ii) medium (10 mg/kg) and (iii) low (5 mg/kg) dosage, (iv) oral-pen-wise (small group) treatment (10 mg/kg), and (v) individual intramuscular injection treatment (10 mg/kg). All groups were treated once a day for five days. In all groups, treatment caused a rise in numbers and proportion of tetracycline resistant coliform bacteria right after treatment, followed by a significant drop by the time where pigs left the nursery unit. Counts and proportion of tetracycline-resistant coliforms did not vary significantly between treatment groups, except immediately after treatment, where the highest treatment dose resulted in the highest number of resistant coliforms. A control group treated with tiamuline did not show significant changes in number or proportion of tetracycline resistant coliforms. Selection for tetracycline-resistant coliforms was significantly correlated to selection for ampicillin- and sulfonamide-resistant, but not to cefotaxime-resistant strains. In conclusion, difference in dose of oxytetracycline and the way the drug was applied did not cause significantly different selection of tetracycline resistant coliform bacteria, under the conditions tested.IMPORTANCE Antimicrobial resistance is a global treat to human health. Treatment of livestock with antimicrobials has a direct impact on this problem, and there is a need to improve the ways that we use antimicrobial in livestock production. We hypothesized that antibiotic resistance development following treatment of diarrhea in nursery pigs could be reduced by either lowering the dose of oxytetracycline or by replacing the commonly used practice of flock treatment with individual or small group treatments, since this would reduce the number of pigs treated. However, the study showed no significant difference between treatment-groups with respect to the number or proportion of tetracycline resistant coliforms selected. The most important conclusion is that under the practical field conditions, there will be no added value in terms of lowering resistance development by exchanging flock treatment with individual or small group treatment of nursery pigs. The reason for lack of effect of single animal treatment is probably that such animals share the environment with treated animals and take up resistant bacteria from the environment.
Er sprængpladen vendt korrekt?
Sprængplader anvendes til overtryksbeskyttelse. Pålideligheden er helt afhængig af, om sprængpladen er vendt rigtigt.

**General information**
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Statistics and Data Analysis
Authors: Hedlund, F. H. (Intern)
Pages: 14-15
Publication date: 2017
Main Research Area: Technical/natural sciences

**Publication information**
Estimation of the transmission dynamics of African swine fever virus within a swine house

The spread of African swine fever virus (ASFV) threatens to reach further parts of Europe. In countries with a large swine production, an outbreak of ASF may result in devastating economic consequences for the swine industry. Simulation models can assist decision makers setting up contingency plans. This creates a need for estimation of parameters. This study presents a new analysis of a previously published study. A full likelihood framework is presented including the impact of model assumptions on the estimated transmission parameters. As animals were only tested every other day, an interpretation was introduced to cover the weighted infectiousness on unobserved days for the individual animals (WIU). Based on our model and the set of assumptions, the within- and between-pen transmission parameters were estimated to $\beta_w = 1.05$ (95% CI 0.62-1.72), $\beta_b = 0.46$ (95% CI 0.17-1.00), respectively, and the WIU = 1.00 (95% CI 0-1). Furthermore, we simulated the spread of ASFV within a pig house using a modified SEIR-model to establish the time from infection of one animal until ASFV is detected in the herd. Based on a chosen detection limit of 2.55% equivalent to 10 dead pigs out of 360, the disease would be detected 13-19 days after introduction.
African swine fever, Epidemiology, Maximum likelihood, Modelling, Transmission

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Source-ID: 2372750021
Publication: Research - peer-review › Journal article – Annual report year: 2017

Explosion i rötkammare med biogas
En biogasreaktor exploderade 1990 på Vejle Centrala reningsverk. Nu, 24 år senare, när biogas är populärare än någonsin, har händelsen helt försvunnit från tillgängliga, öppna källor

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Authors: Hedlund, F. H. (Intern)
Pages: 20-23
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Main Research Area: Technical/natural sciences

Publication information
Journal: Kemivärden Biotech med Kemisk Tidsskrift
Issue number: 4
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.
Fighting Smoldering Fires in Silos – A Cautionary Note on Using Carbon Dioxide to Inert

This communication seeks to draw attention to the hazards of releasing liquid carbon dioxide into environments where an ignitable atmosphere may exist. Static discharges have sufficient energy to ignite flammable vapors and an internal explosion may result when fighting smoldering fires using this approach.

A recent article in Biomass and Bioenergy examines an explosion in a Norwegian wood pellet silo when attempting to suppress a smoldering fire with CO₂. The article argues that the electrostatic hazard of CO₂ is widely under-appreciated and incidents like this are avoidable.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Statistics and Data Analysis
Authors: Hedlund, F. H. (Intern)
Publication date: 2017

Publication information
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Links:
http://www.mydustexplosionresearch.com/smoldering-fires-carbon-dioxide/
Source: PublicationPreSubmission
Source-ID: 139939624
Publication: Communication › Internet publication – Annual report year: 2017
Harnessing Flexibility from Hot and Cold

As has been often reported, electricity systems with high levels of variable wind and solar power generation would benefit from demand flexibility. What is not as often mentioned is that electrification of the transport and heat sectors could exacerbate the need for flexibility, if they are implemented as inflexible loads. This demand could also be made more flexible, but it comes with a cost. The main issue is to identify the cases in which the benefits will outweigh those costs, a matter that will naturally depend on the evolution of specific energy systems. In this article, we lay out some generic principles and characteristics related to heat sector flexibility and demonstrate its possibilities using specific examples. While we generally use the word heat here, most of the discussions also apply to cool, which, after all, is just another form of temperature difference. A major potential for flexibility in the heat sector results from the low cost of storing heat, which allows opportunities to shift electricity demand. Another possibility is to utilize hybrid systems in which either electricity or fuel can be used to produce heat depending on price variations between the two options.
Heating of indoor swimming pools by solar thermal collectors in summerhouses in Denmark

General information
State: Published
Organisations: Department of Civil Engineering, Section for Building Energy, Department of Applied Mathematics and Computer Science, Dynamical Systems, Centre for IT-Intelligent Energy Systems in Cities, Eurisco Aps.
Authors: Dannemand, M. (Intern), Furbo, S. (Intern), Andersen, C. A. (Ekstern), Heller, A. (Intern), Madsen, H. (Intern)
Number of pages: 38
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Main Research Area: Technical/natural sciences
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Høringssvar - Vejledning om definition større uheld 2017
Min kritik af udkast til vejledning om "Definition af større uheld og nærved-uheld på risikovirksomheder", er desværre temmelig grundlæggende. Jeg opfordrer til, at vejledningen ikke udgives. Det er ikke tydeligt, hvilket problem vejledningen søger at løse. Der er alvorlige problemer
Innovative and collaborative industrial mathematics in Europe
This paper presents a brief review of how industrial mathematics, inspired by the Oxford Study Group activity, organized itself in Europe, gave rise to the European Consortium for Mathematics in Industry, the series of European Study Groups with Industry, and to new modes of productive contacts between industry and applied mathematicians in academia.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Hjorth, P. G. (Intern)
Number of pages: 8
Publication date: 2017
Main Research Area: Technical/natural sciences

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Issue number: 2201
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Web of Science (2018): Indexed yes
Integrated Inflammatory Stress (ITIS) Model

During the last decade, there has been an increasing interest in the coupling between the acute inflammatory response and the Hypothalamic–Pituitary–Adrenal (HPA) axis. The inflammatory response is activated acutely by pathogen- or damage-related molecular patterns, whereas the HPA axis maintains a long-term level of the stress hormone cortisol which is also anti-inflammatory. A new integrated model of the interaction between these two subsystems of the inflammatory system is proposed and coined the integrated inflammatory stress (ITIS) model. The coupling mechanisms describing the interactions between the subsystems in the ITIS model are formulated based on biological reasoning and...
its ability to describe clinical data. The ITIS model is calibrated and validated by simulating various scenarios related to endotoxin (LPS) exposure. The model is capable of reproducing human data of tumor necrosis factor alpha, adrenocorticotropic hormone (ACTH) and cortisol and suggests that repeated LPS injections lead to a deficient response. The ITIS model predicts that the most extensive response to an LPS injection in ACTH and cortisol concentrations is observed in the early hours of the day. A constant activation results in elevated levels of the variables in the model while a prolonged change of the oscillations in ACTH and cortisol concentrations is the most pronounced result of different LPS doses predicted by the model.

**General information**

State: Published  
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Technical University of Denmark, North Carolina State University, Frederiksberg Hospital, Roskilde University  
Authors: Bangsgaard, E. O. (Ekstern), Hjorth, P. G. (Intern), Olufsen, M. S. (Ekstern), Mehlsen, J. (Ekstern), Ottesen, J. T. (Ekstern)  
Pages: 1487–1509  
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**Publication information**

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Web of Science (2018): Indexed yes  
BFI (2017): BFI-level 2  
Web of Science (2017): Indexed Yes  
BFI (2016): BFI-level 2  
Scopus rating (2016): CiteScore 1.4 SJR 0.684 SNIP 0.833  
Web of Science (2016): Indexed yes  
BFI (2015): BFI-level 2  
Scopus rating (2015): SJR 0.768 SNIP 0.76 CiteScore 1.34  
BFI (2014): BFI-level 2  
Scopus rating (2014): SJR 0.668 SNIP 0.728 CiteScore 1.32  
BFI (2013): BFI-level 2  
Scopus rating (2013): SJR 0.787 SNIP 0.984 CiteScore 1.68  
ISI indexed (2013): ISI indexed yes  
BFI (2012): BFI-level 2  
Scopus rating (2012): SJR 0.953 SNIP 1.195 CiteScore 2.06  
ISI indexed (2012): ISI indexed yes  
BFI (2011): BFI-level 2  
Scopus rating (2011): SJR 0.95 SNIP 1.112 CiteScore 1.95  
ISI indexed (2011): ISI indexed yes  
Web of Science (2011): Indexed yes  
BFI (2010): BFI-level 2  
Scopus rating (2010): SJR 0.93 SNIP 1.113  
BFI (2009): BFI-level 2  
Scopus rating (2009): SJR 0.872 SNIP 0.936  
BFI (2008): BFI-level 1  
Scopus rating (2008): SJR 0.753 SNIP 1.169  
Scopus rating (2007): SJR 0.877 SNIP 1.154  
Web of Science (2007): Indexed yes  
Scopus rating (2006): SJR 0.778 SNIP 1.088  
Scopus rating (2005): SJR 0.583 SNIP 0.834  
Scopus rating (2004): SJR 0.726 SNIP 1.014  
Scopus rating (2003): SJR 0.73 SNIP 0.81  
Scopus rating (2002): SJR 0.768 SNIP 0.759
Inverse Optimization and Forecasting Techniques Applied to Decision-making in Electricity Markets

This thesis deals with the development of new mathematical models that support the decision-making processes of market players. It addresses the problems of demand-side bidding, price-responsive load forecasting and reserve determination. From a methodological point of view, we investigate a novel approach to model the response of aggregate price-responsive load as a constrained optimization model, whose parameters are estimated from data by using inverse optimization techniques.

The problems tackled in this dissertation are motivated, on one hand, by the increasing penetration of renewable energy production and smart grid technologies in power systems, that is expected to continue growing in the coming years. Non-dispatchable electricity generation cannot ensure a certain production at all times, since it depends on meteorological factors. Also, smart grid technologies are affecting the consumption patterns that the load traditionally exhibited. On the other hand, this thesis is motivated by the decision-making processes of market players. In response to these challenges, this thesis provides mathematical models for decision-making under uncertainty in electricity markets.

Demand-side bidding refers to the participation of consumers, often through a retailer, in energy trading. Under the smart-grid paradigm, the demand bids must reflect the elasticity of the consumers to changes in electricity price. Traditional forecasting models are typically not able to reflect this elasticity, hence we propose two novel approaches to estimate market bids. Both approaches are data-driven and take into account the uncertainty of future factors, as, for example, price. In both cases, demand-side bids that comprise a price-energy term decrease the expected imbalances and also increase the profit of retailers participating in electricity markets.

In the field of load forecasting, this thesis provides a novel approach to model time series and forecast loads under the real-time pricing setup. The relationship between price and aggregate response of the load is characterized by an optimization problem, which is shaped by a set of unknown parameters. Such parameters are estimated from data by using an inverse optimization framework. The usability of the proposed method is studied and we conclude that inverse-optimization-based modeling is a computationally attractive method that outperforms the forecasting capabilities of traditional time series models. Regarding the reserve determination, the special characteristics of the Danish power system do not allow for co-optimizing the unit commitment and reserve requirements. Hence, we propose a probabilistic framework, where the reserve requirements are computed based on scenarios of wind power and load forecast errors and power plant outages. The solution of the stochastic optimization models increases the safety of the overall system while decreases the associated reserve costs, with respect to the method currently used by the Danish TSO.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Saez Gallego, J. (Intern), Madsen, H. (Intern)
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Place of publication: Kgs. Lyngby
Publisher: Technical University of Denmark (DTU)
Original language: English
Series: DTU Compute PHD-2016
Leveraging stochastic differential equations for probabilistic forecasting of wind power using a dynamic power curve

Short-term (hours to days) probabilistic forecasts of wind power generation provide useful information about the 
associated uncertainty of these forecasts. Standard probabilistic forecasts are usually issued on a per-horizon-basis, 
meaning that they lack information about the development of the uncertainty over time or the inter-temporal correlation of 
forecast errors for different horizons. This information is very important for forecast end-users optimizing time-dependent 
variables or dealing with multi-period decision-making problems, such as the management and operation of power 
systems with a high penetration of renewable generation. This paper provides input to these problems by proposing a 
model based on stochastic differential equations that allows generating predictive densities as well as scenarios for wind 
power. We build upon a probabilistic model for wind speed and introduce a dynamic power curve. The model thus 
decomposes the dynamics of wind power prediction errors into wind speed forecast errors and errors related to the 
conversion from wind speed to wind power. We test the proposed model on an out-of-sample period of 1 year for a wind 
farm with a rated capacity of 21 MW. The model outperforms simple as well as advanced benchmarks on horizons ranging 
from 1 to 24 h.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Centre for IT-Intelligent 
Energy Systems in Cities
Authors: Iversen, J. E. B. (Intern), Morales González, J. M. (Intern), Møller, J. K. (Intern), Trombe, P. (Intern), Madsen, H. (Intern)
Pages: 33–44
Publication date: 2017
Main Research Area: Technical/natural sciences
Model for Simulating Fasting Glucose in Type 2 Diabetes and the Effect of Adherence to Treatment.
The primary goal of this paper is to predict fasting glucose levels in type 2 diabetes (T2D) in long-acting insulin treatment. The paper presents a model for simulating insulin-glucose dynamics in T2D patients. The model combines a physiological model of type 1 diabetes (T1D) and an endogenous insulin production model in T2D. We include a review of sources of variance in fasting glucose values in long-acting insulin treatment, with respect to dose guidance algorithms. We use the model to simulate fasting glucose levels in T2D long-acting insulin treatment and compare the results with clinical trial results where a dose guidance algorithm was used. We investigate sources of variance and through simulations evaluate the contribution of adherence to variance and dose guidance quality. The results suggest that the model for simulation of T2D patients is sufficient for simulating fasting glucose levels during titration in a clinical trial. Adherence to insulin injections plays an important role considering variance in fasting glucose. For adherence levels 100%, 70% and 50%, the coefficient of variation of simulated fasting glucose levels were similar to observed variances in insulin treatment. The dose guidance algorithm suggested too large doses in 0.0%, 5.3% and 24.4% of cases, respectively. Adherence to treatment is an important source of variance in long-acting insulin titration.
Modeling Pharmacokinetics and Pharmacodynamics of Glucagon for Simulation of the Glucoregulatory System in Patients with Type 1 Diabetes.

The goal of this thesis was to develop a pharmacokinetics/pharmacodynamics (PK/PD) model for glucagon. The proposed PD model included multiplication of the stimulating glucagon effect and inhibiting insulin effect on the endogenous glucose production (EGP). Moreover, the concentration-response relationship of glucagon and EGP was characterized by a non-linear function, where the response saturated for high concentrations of glucagon. The novel EGP model extended Hovorka’s glucoregulatory model to include the effect of glucagon. The PK/PD model described both regular glucagon and a novel glucagon analogue in healthy dogs. The extended glucoregulatory model translated to the human species and described glucose-insulin-glucagon dynamics in healthy subjects and patients with type 1 diabetes (T1D). The extended glucoregulatory model was successfully validated by leave-one-out cross-validation in seven T1D patients which justified its use for simulations. The final model parameters were estimated from three to four datasets from each patient. The validated extended glucoregulatory model was used for in silico studies. The model replicated a clinical study of the effect of glucagon at varying insulin levels. The simulations also suggested new glucagon doses to be tested in a similar in vivo study to provide new insight to the relationship between insulin, glucagon, and EGP. Finally, the model was used to conduct a large original simulation study investigating an insulin dependent glucagon dosing regimen for treatment of insulin-induced mild hypoglycemia.
Modelling the thermal properties of large diameter fibre ropes

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Center for Intelligent Drug Delivery and Sensing Using Microcontainers and Nanomechanics, University of Southern Denmark
Authors: Oland, E. (Ekstern), Bossolini, E. (Intern), Nielsen, O. W. (Ekstern), Sørensen, M. P. (Intern), Veje, C. (Ekstern)
Publication date: 2017

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Main Research Area: Technical/natural sciences
Conference: 2017 OIPEEC Conference, La Rochelle, France, 04/04/2017 - 04/04/2017
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Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2017

Multi-Period Trading via Convex Optimization
We consider a basic model of multi-period trading, which can be used to evaluate the performance of a trading strategy. We describe a framework for single-period optimization, where the trades in each period are found by solving a convex optimization problem that trades off expected return, risk, transaction cost and holding cost such as the borrowing cost for shorting assets. We then describe a multi-period version of the trading method, where optimization is used to plan a sequence of trades, with only the first one executed, using estimates of future quantities that are unknown when the trades are chosen. The single period method traces back to Markowitz; the multi-period methods trace back to model predictive control. Our contribution is to describe the single-period and multi-period methods in one simple framework, giving a clear description of the development and the approximations made. In this paper, we do not address a critical component in a trading algorithm, the predictions or forecasts of future quantities. The methods we describe in this paper can be thought of as good ways to exploit predictions, no matter how they are made. We have also developed a companion open-source software library that implements many of the ideas and methods described in the paper.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Stanford University
Authors: Boyd, S. (Ekstern), Busseti, E. (Ekstern), Diamond, S. (Ekstern), Kahn, R. N. (Ekstern), Nystrup, P. (Intern), Speth, J. (Ekstern)
Number of pages: 76
Pages: 1-76
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: Foundations and Trends in Optimization
Volume: 3
Issue number: 1
ISSN (Print): 2167-3888
Ratings:
BFI (2014): BFI-level 1
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Original language: English
DOI: 10.1561/2400000023
Source: FindIt
Source-ID: 2372894701
Publication: Research - peer-review › Journal article – Annual report year: 2017
Multi-site solar power forecasting using gradient boosted regression trees

The challenges to optimally utilize weather dependent renewable energy sources call for powerful tools for forecasting. This paper presents a non-parametric machine learning approach used for multi-site prediction of solar power generation on a forecast horizon of one to six hours. Historical power generation and relevant meteorological variables related to 42 individual PV rooftop installations are used to train a gradient boosted regression tree (GBRT) model. When compared to single-site linear autoregressive and variations of GBRT models the multi-site model shows competitive results in terms of root mean squared error on all forecast horizons. The predictive performance and the simplicity of the model setup make the boosted tree model a simple and attractive compliment to conventional forecasting techniques. (C) 2017 Elsevier Ltd. All rights reserved.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Toyota Central R&D Labs
Authors: Persson, C. S. (Intern), Bacher, P. (Intern), Shiga, T. (Ekstern), Madsen, H. (Intern)
Number of pages: 14
Pages: 423-436
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication Information
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BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 4.52 SJR 1.547 SNIP 1.748
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.974 SNIP 2.143 CiteScore 4.61
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.014 SNIP 2.704 CiteScore 4.77
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.058 SNIP 2.92 CiteScore 4.44
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.655 SNIP 2.55 CiteScore 3.65
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.326 SNIP 2.223 CiteScore 3.19
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.419 SNIP 2.161
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.301 SNIP 2.158
Web of Science (2009): Indexed yes
On site characterisation of the overall heat loss coefficient: comparison of different assessment methods by a blind validation exercise on a round robin test box

Several studies have shown that the actual thermal performance of buildings after construction may deviate significantly from its performance anticipated at design stage. As a result, there is growing interest in on site testing as a means to assess real performance. The IEA EBC Annex 58-project ‘Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements’ focused on on site testing and dynamic data analysis methods that can be used to characterise the actual thermal performance and energy efficiency of building components and whole buildings. The research within this project was driven by case studies. The current paper describes one of them: the thermal characterisation of a round robin test box. This test box can be seen as a scale model of a building, and was built by one of the participants. During the project, its fabric properties remained unknown to all other participants. Full scale measurements have been performed on the test box in different countries under real climatic conditions. The obtained dynamic data has been distributed to all participants who had to characterise the thermal performance of the test box’s fabric based on the provided data. The paper compares the result of different techniques, ranging from a simple quasi-stationary analysis to advanced dynamic data analysis methods, which can be used to characterise the thermal performance based on on-site collected data.

General information
State: Accepted/In press
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, University of Leuven, CIEMAT
Authors: Roels, S. (Ekstern), Bacher, P. (Intern), Bauwens, G. (Ekstern), Castaño, S. (Ekstern), Jiménez, M. J. (Ekstern), Madsen, H. (Intern)
Pages: 179-189
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: Energy and Buildings
Volume: 153
ISSN (Print): 0378-7788
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
Relationship between Optimum Mini-doses of Glucagon and Insulin Levels when Treating Mild Hypoglycaemia in Patients with Type 1 Diabetes - A Simulation Study

Hypoglycaemia remains the main limiting factor in type 1 diabetes management. We developed an insulin-dependent glucagon dosing regimen for treatment of mild hypoglycaemia based on simulations. A validated glucose-insulin-glucagon model was used to describe seven virtual patients with insulin pump-treated type 1 diabetes. In each simulation, one of ten different and individualized subcutaneous insulin boluses was administered to decrease plasma glucose (PG) from 7.0 to ≤3.9 mmol/l. Insulin levels were estimated as ratio of actual to baseline serum insulin concentration (se/ba-insulin), insulin on board (IOB) or percentage of IOB to total daily insulin dose (IOB/TDD). Insulin bolus sizes were chosen to provide pre-defined insulin levels when PG reached 3.9 mmol/l, where one of 17 subcutaneous glucagon boluses was administered. Optimum glucagon bolus to treat mild hypoglycaemia at varying insulin levels was the lowest dose that in most patients caused PG peak between 5.0 and 10.0 mmol/l and sustained PG ≥ 3.9 mmol/l for 2 hr after the bolus. PG response to glucagon declined with increasing insulin levels. The glucagon dose to optimally treat mild hypoglycaemia depended exponentially on insulin levels, regardless of how insulin was estimated. A 125-μg glucagon dose was needed to optimally treat mild hypoglycaemia when insulin levels were equal to baseline levels. In contrast, glucagon doses >500 µg were needed when se/ba-insulin >2.5, IOB >2.0 U or IOB/TDD >6%. Although the proposed model-based glucagon regimen needs confirmation in clinical trials, this is the first attempt to develop an insulin-dependent glucagon dosing regimen for treatment of insulin-induced mild hypoglycaemia in patients with type 1 diabetes.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, University of Copenhagen, Zealand Pharma A/S
Authors: Ranjan, A. (Ekstern), Wendt, S. L. (Intern), Schmidt, S. (Ekstern), Madsbad, S. (Ekstern), Holst, J. J. (Ekstern), Madsen, H. (Intern), Knudsen, C. B. (Ekstern), Jørgensen, J. B. (Intern), Nørgaard, K. (Ekstern)
Pages: n/a-n/a
Publication date: 2017
Main Research Area: Technical/natural sciences

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Web of Science (2017): Indexed yes
BFIRating (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.57
BFIRating (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.64
Web of Science (2015): Indexed yes
BFIRating (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.11
Web of Science (2014): Indexed yes
BFIRating (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.28
ISI indexed (2013): ISI indexed yes
BFIRating (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.12
ISI indexed (2012): ISI indexed yes
BFIRating (2011): BFI-level 1
Scopus rating (2011): CiteScore 2.45
ISI indexed (2011): ISI indexed yes
BFIRating (2010): BFI-level 1
BFIRating (2009): BFI-level 2
Web of Science (2009): Indexed yes
BFIRating (2008): BFI-level 2
Web of Science (2006): Indexed yes
Risici ved midlertidige oplag af farligt gods.


[English summary] Following a major fireworks accident in Seest (2004), the statutory order implementing the EU Seveso directive in Denmark was enlarged in 2005 to cover also temporary storage of dangerous substances at transportation hubs such as marine terminals and railway yards. The rationale is quite sensible – the risk posed to nearby communities can be permanent even though the individual cargo is present temporarily only. The enlargement of order was ill conceived however, and implementation of the new measures has been troubled, in particular because transportation companies only have information on dangerous goods as provided in ADR/RID/IMO transportation documents, and the nature of this information is incompatible with the Seveso legislation's definition of dangerous substances. The paper provides a critical commentary on the rule-making and subsequent consultation processes and examines the dismal implementation status 12 years later (2017).

Sikring af risikovirksomheder

Nu skal risikovirksomheder udføre en sårbarhedsvurdering. Det er en følge af regeringens terrorhandlingsplan. En vejledning har netop været i høring.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science , Dynamical Systems, Statistics and Data Analysis
Authors: Hedlund, F. H. (Intern)
Pages: 20-23
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: Dansk Kemi
Volume: 98
Issue number: 10
ISSN (Print): 0011-6335
Ratings:
ISI indexed (2013): ISI indexed no
ISI indexed (2012): ISI indexed no
ISI indexed (2011): ISI indexed no
Web of Science (2007): Indexed yes
Web of Science (2004): Indexed yes
Original language: Danish
Electronic versions:
Risici_ved_midlertidige_oplag_af_farligt_gods.pdf
Source: PublicationPreSubmission
Source-ID: 138484004
Publication: Communication › Journal article – Annual report year: 2017
Simulating clinical studies of the glucoregulatory system: *in vivo meets in silico*

In this report we use a validated model of the glucoregulatory system including effects of insulin and glucagon for simulation studies in seven type 1 diabetes patients. Using simulations, we replicate the results from a clinical study investigating the effect of micro-doses of glucagon on glucose metabolism at varying ambient insulin levels. The report compares *in vivo* and *in silico* results head-to-head, and discusses similarities and differences. We design and simulate simple studies to emphasize the implications of some glucoregulatory dynamics which are ignored in most previous clinical studies: the effect of discontinuing insulin and glucose infusions prior to glucagon administration, the delayed effect of insulin, timing of data sampling, and carryover effects from multiple subcutaneous doses of glucagon. We also use simulations to discuss two hypotheses of how insulin and glucagon might interact in influencing the glucose response. Following the simulations we propose a study design that potentially could explore if the hypotheses are true or false.

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Copenhagen University Hospital, Zealand Pharma A/S, University of Copenhagen
Authors: Wendt, S. L. (Intern), Ranjan, A. (Ekstern), Møller, J. K. (Intern), Boye Knudsen, C. (Ekstern), Holst, J. J. (Ekstern), Madsbad, S. (Ekstern), Madsen, H. (Intern), Nørgaard, K. (Ekstern), Jørgensen, J. B. (Intern)
Number of pages: 35
Publication date: 2017

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Number: 01
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Main Research Area: Technical/natural sciences
Glucagon, Glucoregulatory system, Glucose, Insulin, Simulation
Electronic versions:
tr17_01_Wendt_SL.pdf
Publication: Report – Annual report year: 2017

**skoleklima.dk – A platform to monitor air quality and thermal comfort in classrooms, developed for teachers and students**

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Høje Taastrup Kommune, Københavns Universitet
Authors: Cali, D. (Intern), Bachalarz, M. (Intern), Bacher, P. (Intern), Madsen, H. (Intern), Lex, S. W. (Forskerdatabase), Koed Rasmussen, M. (Ekstern)
Number of pages: 1
Spatial bias and uncertainty in numerical weather predictions for urban runoff forecasts with long time horizons

Numerical Weather Predictions (NWP) can be used to forecast urban runoff with long lead times. However, NWP exhibit large spatial uncertainties and using forecasted precipitation directly above the catchment might therefore not be an ideal approach in an online setup. We use the Danish Meteorological Institute’s NWP ensemble and investigate a large spatial neighborhood around the catchment over a two-year period. When compared against in-sewer observations, runoff forecasts forced with precipitation from north-east of the catchment are most skillful. This highlights spatial biases in the coupled hydro-meteorological setup, which a forecaster should be aware of.

Stochastic Greybox Modeling for Control of an Alternating Activated Sludge Process

We present a stochastic greybox model of a BioDenitro WWTP that can be used for short time horizon Model Predictive Control. The model is based on a simplified ASM1 model and takes model uncertainty in to account. It estimates unmeasured state variables in the system, e.g. the inlet concentration or the sensor measurements in case of temporary sensor faults. This improves control performance without adding additional or redundant sensors. We fitted the parameters of the model to actual plant data and demonstrate the state estimation capabilities with this data set. The model now runs online at a WWTP in Denmark
Stochastic model of wind-fuel cell for a semi-dispatchable power generation

Hybrid systems are implemented to improve the efficiency of individual generation technologies by complementing each other. Intermittence is a challenge to overcome especially for renewable energy sources for electric generation, as in the case of wind power. This paper proposes a hybrid system as an approach for reducing and overcoming the volatility of wind power, by implementing storage technology, forecasts and predictive control. The proposed hybrid system, which is suitable for the distributed generation level, consists of a wind generator, an electrolyzer, hydrogen storage and a polymer electrolyte membrane fuel cell, which are embedded in one complete system with the wind power. This study uses historic wind speed data from Mexico; the forecasts are obtained using the recursive least square algorithm with a forgetting factor. The proposed approach provides probabilistic information for short-term wind power generation and electric generation as the outcome of the hybrid system. A method for a semi-dispatchable electric generation based on time series analysis is presented, and the implementation of wind power and polymer electrolyte membrane fuel cell models controlled by a model predictive control approach is developed.
Stochastic Programming for Fuel Supply Planning of Combined Heat and Power Plants

The consumption of biomass to produce power and heat has increased due to the carbon neutral policies. Combined heat and power (CHP) plants often combine biomass with other fuels, e.g., natural gas. The negotiation process for supply contracts involves many uncertainties due to the long planning horizon. The demand for biomass is uncertain, and heat demand and electricity prices vary during the planning period. We propose a method using stochastic optimization to support the biomass and natural gas supply planning for CHP plants including short-term decisions for optimal market participation.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Guericke, D. (Intern), Blanco, I. (Intern), Morales González, J. M. (Intern), Madsen, H. (Intern)
Number of pages: 1
Publication date: 2017
Main Research Area: Technical/natural sciences
Electronic versions:
Source: PublicationPreSubmission
Source-ID: 139979336
Publication: Research - peer-review » Conference abstract for conference – Annual report year: 2017

Svigt af inertgas purge medførte eksplosion i beholder

General information
State: Published
Synergies between energy supply networks

Energy system integration uses a whole-system approach to optimize the synergies between energy supply networks to facilitate and coordinate the grid integration of distributed energy resources while enabling the synergies and conflicts between the local distribution networks and the national level objectives to be understood and optimally coordinated. The latest research on the network coupling technologies analysis of synergies between energy supply networks and optimal use of synergies in network operation is discussed. A diagram on the possible interactions between different energy networks and integration of local renewables including solar energy wind geothermal waste heat and biomass is presented.

General information

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Cardiff University, University of Pisa, KU Leuven, University of Groningen, Karlsruhe Institute of Technology KIT
Authors: Wu, J. (Ekstern), Yan, J. (Ekstern), Desideri, U. (Ekstern), Deconinck, G. (Ekstern), Madsen, H. (Intern), Huitema, G. (Ekstern), Kolb, T. (Ekstern)
Number of pages: 5
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Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information

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Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 7.78 SJR 3.058 SNIP 2.573
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2.912 SNIP 2.61 CiteScore 6.4
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Tank für Überschusshefe versagt – mit katastrophalen Folgen
Ein großer Tank für Überschusshefe flog in die Luft und nur noch die Bodenplatte und der Tankinhalt blieben zurück. Obwohl der Tank nicht für Überdruck ausgelegt war, wurde er auf "sehr geringem Überdruck" gehalten, um störende Schaumentwicklung zu verhindern. Der Brauerei waren die Gefahren durch Druckluft nicht bekannt. Der in diesem Artikel beschriebene Unfall soll aufzeigen, dass Vorsicht geboten ist, wenn ein ursprünglich für atmosphärischen Druck ausgelegter Tank auf Betrieb mit leichtem Überdruck abgeändert wird

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Statistics and Data Analysis, COWI A/S
Authors: Hedlund, F. H. (Intern), Selig, R. S. (Ekstern)
Pages: 229-232
Thermal stratification built up in hot water tank with different inlet stratifiers

Thermal stratification in a water storage tank can strongly increase the thermal performance of solar heating systems. Thermal stratification can be built up in a storage tank during charge, if the heated water enters through an inlet stratifier. Experiments with a test tank have been carried out in order to elucidate how well thermal stratification is established in the tank with differently designed inlet stratifiers under different controlled laboratory conditions. The investigated inlet stratifiers are from Solvis GmbH & Co KG and EyeCular Technologies ApS. The inlet stratifier from Solvis GmbH is a rigid plastic pipe with holes for each 30 cm. The holes are designed with flaps preventing counter flow into the pipe. The inlet stratifier from EyeCular Technologies ApS is made of a flexible polymer with openings all along the side and in the full length of the stratifier. The flexibility of the stratifier prevents counterflow. The tests have shown that both types of inlet stratifiers had an ability to create stratification in the test tank under the different test conditions. The stratifier from EyeCular Technologies ApS had a better performance at low flows of 1-2 l/min and the stratifier for Solvis GmbH & Co KG had a better performance at 4 l/min. In the intermediate charge test the stratifier from EyeCular Technologies ApS had a better performance in terms of maintaining the thermal stratification in the storage tank while charging with a relative low temperature. [All rights reserved Elsevier].

General information
State: Published
Organisations: Department of Civil Engineering, Section for Building Energy, Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Dragsted, J. (Intern), Furbo, S. (Intern), Dannemand, M. (Intern), Bava, F. (Intern)
Number of pages: 12
Pages: 414-425
Publication date: 2017
Main Research Area: Technical/natural sciences
Urban runoff forecasting with ensemble weather predictions

This research shows how ensemble weather forecasts can be used to generate urban runoff forecasts up to 53 hours into the future. The results highlight systematic differences between ensemble members that needs to be accounted for when these forecasts are used in practice.

General information

State: Published
Organisations: Department of Environmental Engineering, Urban Water Systems, Department of Applied Mathematics and Computer Science, Dynamical Systems
Number of pages: 2
Publication date: 2017
Main Research Area: Technical/natural sciences
Electronic versions: Nordiwa_JOWI_Abstract_20170316.pdf
Source: PublicationPreSubmission
Source-ID: 139073611
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2017
Validation of a Simulation Model Describing the Glucose-Insulin-Glucagon Pharmacodynamics in Patients with Type 1 Diabetes

Currently, no consensus exists on a model describing endogenous glucose production (EGP) as a function of glucagon concentrations. Reliable simulations to determine the glucagon dose preventing or treating hypoglycemia or to tune a dual-hormone artificial pancreas control algorithm need a validated glucoregulatory model including the effect of glucagon.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Copenhagen Center for Health Technology, Center for Energy Resources Engineering, Copenhagen University Hospital, Zealand Pharma A/S, University of Copenhagen
Authors: Wendt, S. L. (Intern), Ranjan, A. (Ekstern), Møller, J. K. (Intern), Schmidt, S. (Ekstern), Boye Knudsen, C. (Ekstern), Holst, J. J. (Ekstern), Madsbad, S. (Ekstern), Madsen, H. (Intern), Nørgaard, K. (Ekstern), Jørgensen, J. B. (Intern)
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Main Research Area: Technical/natural sciences
Electronic versions: ATTD2017_SLW_final.pdf
Source: PublicationPreSubmission
Source-ID: 129907816
Publication: Research › Poster – Annual report year: 2017

Validation of the dynamic wake meander model with focus on tower loads: Paper

This paper presents a comparison between measured and simulated tower loads for the Danish offshore wind farm Nysted 2. Previously, only limited full scale experimental data containing tower load measurements have been published, and in many cases the measurements include only a limited range of wind speeds. In general, tower loads in wake conditions are very challenging to predict correctly in simulations. The Nysted project offers an improved insight to this field as six wind turbines located in the Nysted II wind farm have been instrumented to measure tower top and tower bottom moments. All recorded structural data have been organized in a database, which in addition contains relevant wind turbine SCADA data as well as relevant meteorological data - e.g. wind speed and wind direction - from an offshore mast located in the immediate vicinity of the wind farm. The database contains data from a period extending over a time span of more than 3 years. Based on the recorded data basic mechanisms driving the increased loading experienced by wind turbines operating in offshore wind farm conditions have been identified, characterized and modeled. The modeling is based on the Dynamic Wake Meandering (DWM) approach in combination with the state-of-the-art aeroelastic model HAWC2, and has previously as well as in this study shown good agreement with the measurements. The conclusions from the study have several parts. In general the tower bending and yaw loads show a good agreement between measurements and simulations. However, there are situations that are still difficult to match. One is tower loads of single-wake operation near rated ambient wind speed for single wake situations for spacing’s around 7-8D. A specific target of the study was to investigate whether the largest tower fatigue loads are associated with a certain downstream distance. This has been identified in both simulations and measurements, though a rather flat optimum is seen in the measurements.

General information
State: Published
Organisations: Department of Wind Energy, Wind turbine loads & control, Test and Measurements, Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Larsen, T. J. (Intern), Larsen, G. C. (Intern), Pedersen, M. M. (Intern), Enevoldsen, K. (Intern), Madsen, H. A. (Intern)
Number of pages: 10
Publication date: 2017

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Title of host publication: Wake Conference 2017
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Series: Journal of Physics: Conference Series
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Main Research Area: Technical/natural sciences
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Electronic versions:
Validation of the dynamic wake meander model with focus on tower loads: Paper
This paper presents a comparison between measured and simulated tower loads for the Danish offshore wind farm Nysted 2. Previously, only limited full scale experimental data containing tower load measurements have been published, and in many cases the measurements include only a limited range of wind speeds. In general, tower loads in wake conditions are very challenging to predict correctly in simulations. The Nysted project offers an improved insight to this field as six wind turbines located in the Nysted II wind farm have been instrumented to measure tower top and tower bottom moments. All recorded structural data have been organized in a database, which in addition contains relevant wind turbine SCADA data as well as relevant meteorological data - e.g. wind speed and wind direction - from an offshore mast located in the immediate vicinity of the wind farm. The database contains data from a period extending over a time span of more than 3 years. Based on the recorded data basic mechanisms driving the increased loading experienced by wind turbines operating in offshore wind farm conditions have been identified, characterized and modeled. The modeling is based on the Dynamic Wake Meandering (DWM) approach in combination with the state-of-the-art aeroelastic model HAWC2, and has previously as well as in this study shown good agreement with the measurements. The conclusions from the study have several parts. In general the tower bending and yaw loads show a good agreement between measurements and simulations. However, there are situations that are still difficult to match. One is tower loads of single-wake operation near rated ambient wind speed for single wake situations for spacing’s around 7-8D. A specific target of the study was to investigate whether the largest tower fatigue loads are associated with a certain downstream distance. This has been identified in both simulations and measurements, though a rather flat optimum is seen in the measurements.

General information
State: Published
Organisations: Department of Wind Energy, Wind turbine loads & control, Test and Measurements, Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Larsen, T. J. (Intern), Larsen, G. C. (Intern), Pedersen, M. M. (Intern), Enevoldsen, K. (Intern), Madsen, H. A. (Intern)
Number of pages: 10
Publication date: 2017

Publication information
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Original language: English
Volume: 854
Main Research Area: Technical/natural sciences
Electronic versions:
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Publication: Research › Sound/Visual production (digital) – Annual report year: 2017

Warum ist es so schwierig, die lateralen Gleisstörungen durch Messungen der Fahrzeugdynamik zu bestimmen

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Christiansen, L. E. (Intern), True, H. (Intern)
Pages: 133-139
Publication date: 2017
Conference: 44. Tagung „Moderne Schienenfahrzeuge“, Graz, Austria, 10/09/2017 - 10/09/2017
Main Research Area: Technical/natural sciences

Publication information
Journal: ZEV rail
Original language: German
Source: PublicationPreSubmission
Source-ID: 139204720
Publication: Research - peer-review › Conference article – Annual report year: 2017
Why is it so difficult to determine the lateral Position of the Rails by a Measurement of the Motion of an Axle on a moving Vehicle?

Several attempts of measuring the exact location of the rails by the use of ordinary vehicles have been made. While the method works reasonably well in the vertical direction, the results of the lateral measurements made with different vehicles are so widely scattered that it is virtually impossible to draw any conclusions. We may therefore ask: does a wheel set follow the track disturbances exactly? In this article we investigate the lateral dynamics of a half-car vehicle model with two-axle bogies running on a rigid tangent track with sinusoidal lateral disturbances of the rails. The wavelength, the amplitude and the phase between the rail disturbances are varied. Two different vehicle speeds are investigated. One speed is under and the other above the vehicle critical speed. In the article we show examples of axle motions that do not follow the track disturbances in phase, amplitude or period or several of these together. The results are discussed, and we must conclude that it is in general impossible to determine the track geometry from the motion of a wheel set.
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 Neyman-Pearson 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.

Adaptive Test Schemes for Control of Paratuberculosis in Dairy Cows

Paratuberculosis is a chronic infection that in dairy cattle causes reduced milk yield, weight loss, and ultimately fatal diarrhea. Subclinical animals can excrete bacteria (Mycobacterium avium ssp. paratuberculosis, MAP) in feces and infect other animals. Farmers identify the infectious animals through a variety of test-strategies, but are challenged by the lack of perfect tests. Frequent testing increases the sensitivity but the costs of testing are a cause of concern for farmers. Here, we used a herd simulation model using milk ELISA tests to evaluate the epidemiological and economic consequences of continuously adapting the sampling interval in response to the estimated true prevalence in the herd. The key results were that the true prevalence was greatly affected by the hygiene level and to some extent by the test-frequency. Furthermore, the choice of prevalence that will be tolerated in a control scenario had a major impact on the true prevalence in the normal hygiene setting, but less so when the hygiene was poor. The net revenue is not greatly affected by the test-strategy, because of the general variation in net revenues between farms. An exception to this is the low hygiene herd, where frequent testing results in lower revenue. When we look at the probability of eradication, then it is correlated with the testing frequency and the target prevalence during the control phase. The probability of eradication is low in the low hygiene herd, and a test-and-cull strategy should probably not be the primary strategy in this herd. Based on this study we suggest that, in order to control MAP, the standard Danish dairy farm should use an adaptive strategy where a short sampling interval of three months is used when the estimated true prevalence is above 1%, and otherwise use a long sampling interval of one year.
A Data-Driven Bidding Model for a Cluster of Price-Responsive Consumers of Electricity

This paper deals with the market-bidding problem of a cluster of price-responsive consumers of electricity. We develop an inverse optimization scheme that, recast as a bilevel programming problem, uses price-consumption data to estimate the complex market bid that best captures the price-response of the cluster. The complex market bid is defined as a series of marginal utility functions plus some constraints on demand, such as maximum pick-up and drop-off rates. The proposed modeling approach also leverages information on exogenous factors that may influence the consumption behavior of the cluster, e.g., weather conditions and calendar effects. We test the proposed methodology for a particular application: forecasting the power consumption of a small aggregation of households that took part in the Olympic Peninsula project.
Results show that the price-sensitive consumption of the cluster of flexible loads can be largely captured in the form of a complex market bid, so that this could be ultimately used for the cluster to participate in the wholesale electricity market.
A herd- and cow-specific decision support tool for control of mastitis

**General information**

State: Published
Organisations: National Veterinary Institute, Section for Epidemiology, Department of Applied Mathematics and Computer Science, Dynamical Systems, University of Copenhagen
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Number of pages: 1
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Main Research Area: Technical/natural sciences

An Efficient UD-Based Algorithm for the Computation of Maximum Likelihood Sensitivity of Continuous-Discrete Systems

This paper addresses maximum likelihood parameter estimation of continuous-time nonlinear systems with discrete-time measurements. We derive an efficient algorithm for the computation of the log-likelihood function and its gradient, which can be used in gradient-based optimization algorithms. This algorithm uses UD decomposition of symmetric matrices and the array algorithm for covariance update and gradient computation. We test our algorithm on the Lotka-Volterra equations. Compared to the maximum likelihood estimation based on finite difference gradient computation, we get a significant speedup without compromising the numerical accuracy.

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems
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Pages: 3048-3053
Publication date: 2016

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.

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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.

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State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Copenhagen University Hospital
Approaches for Accommodating Demand Response in Operational Problems and Assessing its Value
This thesis deals with the development of operational models of demand response and the evaluation of this novel resource within existing frameworks for power system dispatch and market clearing.

Increasing shares of power generation from variable renewable sources, and climate change policies that discourage the use of fossil fuel intensive power plants, are among the factors that are currently driving the evolution of power systems towards greater flexibility. Activating the latent flexibility of electricity consumption through demand response can contribute towards facilitating this evolution. However, before the necessary investments can be made to establish and operate this novel resource, its value must be determined.

As with all current power system resources, if distributed demand response is deployed on a large scale it will be required to interface with the power system and market operators through established frameworks. Such frameworks are not suited to interaction with large numbers of individual flexible loads, so it is necessary to establish a representation of their aggregated flexibility that can be effectively communicated to system and market operators. In this thesis we introduce the concept of a saturation curve, which represents the flexibility offered by a broad class of flexible loads capable of providing load shifting demand response: thermal-electric loads such as refrigeration and heating. From this saturation curve we extract dispatch and market offering structures for demand response that respect the physical characteristics and constraints of the individual flexible loads within an aggregate population, while being limited in complexity to that allowable within current operational power system frameworks.

An evaluation of demand response must consider both the social welfare value it generates by reducing overall power system operation costs, and the commercial value it can accrue by participating in competitive electricity markets. Social welfare value provides an indicator of the viability of any new power system resource, but does not guarantee that the necessary investments will be made to establish and operate the resource. A positive commercial assessment will signal to investors that the resource can offer a return on their investment, and that it can thrive in a competitive environment. We consider both the social welfare and commercial value of demand response in this thesis, by simulating the deployment of our specialised operational models of demand response within power system dispatch frameworks and by developing innovative trading strategies for demand response on the day-ahead and intraday markets.

We find through the combined modelling and analysis contained in this thesis that the value offered by demand response is very low under current power system conditions, and when it is restricted to operating within existing operational frameworks. Prices and costs on the studied power systems are insufficient to allow demand response to generate significant value or revenue through energy arbitrage or load curtailment. This does not rule out that there maybe certain power systems, or sections thereof, that are currently experiencing sufficient resource scarcity to result in a favourable environment for the successful implementation of demand response. At the current time however, our research finds that the outlook for the widespread deployment of demand response is poor.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems
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Associations between health, management and antimicrobial use in Danish swine and veal calves

General information
State: Published
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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Statistics and Data Analysis, COWI A/S
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Pages: 20-22
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Capacity expansion of stochastic power generation under two-stage electricity markets

Energy imbalances due to power forecast errors have a significant impact on both the cost of operating the power system and the profitability of stochastic power generating units. In this paper, we propose a modeling framework to analyze the effect of the costs of these imbalances on the expansion of stochastic power generating units. This framework includes the explicit representation of a day-ahead and a balancing market-clearing mechanisms to properly capture the impact of forecast errors of power production on the short-term operation of a power system. The proposed generation expansion problems are first formulated from the standpoint of a social planner to characterize a perfectly competitive market. We investigate the effect of two paradigmatic market designs on generation expansion planning: a day-ahead market that is cleared following a conventional cost merit-order principle, and an ideal market-clearing procedure that determines day-ahead dispatch decisions accounting for their impact on balancing operation costs. Furthermore, we reformulate the proposed models to determine the optimal expansion decisions that maximize the profit of a collusion of stochastic power producers in order to explore the effects of competition at the investment level. The proposed models are first formulated as multi-level programming problems and then recast, under certain assumptions, as single-level mixed-integer linear or non-linear optimization problems using duality theory. The variability of the forecast of the stochastic power production and the demand level throughout the planning horizon is modeled using yearly duration curves. Likewise, the uncertainty pertaining to power forecast errors is characterized through scenario sets. The main features and results of the proposed models are discussed using an illustrative example and a more realistic case study based on the Danish power system.
Commitment and dispatch of heat and power units via affinely adjustable robust optimization

The joint management of heat and power systems is believed to be key to the integration of renewables into energy systems with a large penetration of district heating. Determining the day-ahead unit commitment and production schedules for these systems is an optimization problem subject to uncertainty stemming from the unpredictability of demand and prices for heat and electricity. Furthermore, owing to the dynamic features of production and heat storage units as well as to the length and granularity of the optimization horizon (e.g., one whole day with hourly resolution), this problem is in essence a multi-stage one. We propose a formulation based on robust optimization where recourse decisions are approximated as linear or piecewise-linear functions of the uncertain parameters. This approach allows for a rigorous modeling of the uncertainty in multi-stage decision-making without compromising computational tractability. We perform an extensive numerical study based on data from the Copenhagen area in Denmark, which highlights important features of the proposed model. Firstly, we illustrate commitment and dispatch choices that increase conservativeness in the robust optimization approach. Secondly, we appraise the gain obtained by switching from linear to piecewise-linear decision rules within robust optimization. Furthermore, we give directions for selecting the parameters defining the uncertainty set (size, budget) and assess the resulting trade-off between average profit and conservativeness of the solution. Finally, we perform a thorough comparison with competing models based on deterministic optimization and stochastic programming.

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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%.

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Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Copenhagen University Hospital  

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Source-ID: 126411761  
Publication: Research - peer-review › Article in proceedings – Annual report year: 2016

**Compound waves in a higher order nonlinear model of thermoviscous fluids**
A generalized traveling wave ansatz is used to investigate compound shock waves in a higher order nonlinear model of a thermoviscous fluid. The fluid velocity potential is written as a traveling wave plus a linear function of space and time. The latter offers the possibility of predicting the outcome of interacting shock waves, i.e. shock jump heights and wave velocities after collisions and overtakes. The stability of the linear solution part is investigated and a criterion for its stability is determined. For a number of instances, the numerical results show formation of rarefaction waves. By using a similarity transformation, analytical expressions for these rarefaction waves are found in the limit of no dissipation. Examples of compound shock waves are illustrated by numerical simulations.

**General information**
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- Web of Science (2016): Indexed yes
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- Web of Science (2014): Indexed yes
- BFI (2013): BFI-level 1
Detecting change points in VIX and S&P 500: A new approach to dynamic asset allocation

The purpose of dynamic asset allocation (DAA) is to overcome the challenge that changing market conditions present to traditional strategic asset allocation by adjusting portfolio weights to take advantage of favorable conditions and reduce potential drawdowns. This article proposes a new approach to DAA that is based on detection of change points without fitting a model with a fixed number of regimes to the data, without estimating any parameters and without assuming a specific distribution of the data. It is examined whether DAA is most profitable when based on changes in the Chicago Board Options Exchange Volatility Index or change points detected in daily returns of the S&P 500 index. In an asset universe consisting of the S&P 500 index and cash, it is shown that a dynamic strategy based on detected change points significantly improves the Sharpe ratio and reduces the drawdown risk when compared with a static, fixed-weight benchmark.

General information

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Pages: 361-374
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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

State: Published
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.

General information
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, Scientific Computing, University of California, Los Angeles
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Dynamics of a physiologically structured population in a time-varying environment

Physiologically structured population models have become a valuable tool to model the dynamics of populations. In a stationary environment such models can exhibit equilibrium solutions as well as periodic solutions. However, for many organisms the environment is not stationary, but varies more or less regularly. In order to understand the interaction between an external environmental forcing and the internal dynamics in a population, we examine the response of a physiologically structured population model to a periodic variation in the food resource. We explore the addition of forcing in two cases: (A) where the population dynamics is in equilibrium in a stationary environment, and (B) where the population dynamics exhibits a periodic solution in a stationary environment. When forcing is applied in case A, the solutions are mainly periodic. In case B the forcing signal interacts with the oscillations of the unforced system, and both periodic and irregular (quasi-periodic or chaotic) solutions occur. In both cases the periodic solutions include one and multiple period cycles, and each cycle can have several reproduction pulses.
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.
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.

Economic valuation of heat pumps and electric boilers in the Danish energy system

Heat pumps (HP) and electric immersion boilers (EB) have great potential to increase flexibility in energy systems. In parallel, decreasing taxes on electricity-based heat production are creating a more favorable economic environment for the deployment of these units in Denmark. In this paper, the economic value of heat pumps and electric boilers is assessed by simulating their day-to-day market performance using a novel operational strategy based on two-stage stochastic programming. This stochastic model is employed to optimize jointly the daily operation of HPs and EBs along with the Combined Heat and Power (CHP) units in the system. Uncertainty in the heat demand and power price is modeled via scenarios representing different plausible paths for their future evolution. A series of case-studies are performed using real-world data for the heat and power systems in the Copenhagen area during four representative weeks of 2013. We show that the use of stochastic operational models is critical, as standard deterministic models provide an overestimation of the added benefits from the installation of HPs and EBs, thus leading to over-investment in capacity. Furthermore, we perform sensitivity studies to investigate the effect on market performance of varying capacity and efficiency for these units, as well as of different levels of prices in the electricity market. We find that these parameters substantially affect the profitability of heat pumps and electric boilers, hence, they must be carefully assessed by potential investors.
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.

General information
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Relations
Experimentation and numerical modeling of cyclic voltammetry for electrochemical micro-sized sensors under the influence of electrolyte flow

In this study, we perform experimental studies as well as simulations for cyclic voltammetry (CV) of the redox couple Fe(III)/(CN)₆³⁻/Fe(II)/(CN)₆⁴⁻ on a gold plated ECC biosensor encapsulated by a microfluidic system. We examine the effect of flow rate, scan rate, varying supporting electrolyte, exchange current density and the position of electrode on the CV measurements. The results show that at a relatively high flow (250 μ/L) and low scan rates (50 - 200 m/V/s), the current response is limited by the convection due to quick supply of fresh ions at the electrode surface which leads to fading hysteresis of the recorded CV. However, at high scan rates (250 m/V/s) and slow flow rates (50 - 200 μ/L), peak currents are recorded which means that mass transport is dominated by the diffusion mechanism and a quasi-steady state of CV is recorded. In the case of insufficient supporting electrolyte, the excess charges generated during scan will lead to ohmic distortion of the electrolyte solution and consequently result into a ramping effect of the recorded CV. However, for sufficient amount of supporting electrolyte (200 mM), the simulation results show good agreement with the experimental data. In addition, the results also show that a decrease in exchange current density leads to a shift in the peak current of the recorded CV. Finally, the results also demonstrate that the working electrode at the center of the fluidic cell records accurate measurement than placing the electrode at the bottom of the cell. The numerical results and the experimental data show both qualitative good agreement and quantitative good agreement.
Fatal Accidents During Marine Transport of Wood Pellets Due to Off-gassing – Experiences from Denmark

The atmosphere in unventilated wood pellet storage confinements, such as the cargo hold of marine vessels transporting pellets in solid bulk, can be severely oxygen deficient and contain deadly concentrations of harmful gasses, of which the most feared is the poisonous and odour-less carbon monoxide. The hazard has been known for over a decade and has been responsible for many accidents. We examine three fatal accidents on marine vessels in or near Danish waters and argue that they share strikingly similar aetiologies, if not repetitive patterns. It is generally recognized that accidents should be thoroughly investigated and lessons learned shared widely in order to minimize the number of times the same lessons have to be learned. The three Danish cases suggest that this learning process is deeply troubled for the solid biomass segment. The International Maritime Organization IMO/SOLAS has recently revised its guidance on entering enclosed spaces aboard ships in response to the ongoing problem of confined space incidents. We argue that the interpretation of the concept of an "enclosed space" is of utmost importance because accidents take place in rooms that are not considered enclosed by the crew.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Statistics and Data Analysis, COWI A/S, Danish Maritime Accident Investigation Board (DMAIB)
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Har tanken et svagt tag?

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Hidden Markov Models for indirect classification of occupant behaviour

Even for similar residential buildings, a huge variability in the energy consumption can be observed. This variability is mainly due to the different behaviours of the occupants and this impacts the thermal (temperature setting, window opening, etc.) as well as the electrical (appliances, TV, computer, etc.) consumption.

It is very seldom to find direct observations of occupant presence and behaviour in residential buildings. However, given the increasing use of smart metering, the opportunity and potential for indirect observation and classification of occupants’ behaviour is possible. This paper focuses on the use of Hidden Markov Models (HMMs) to create methods for indirect observations and characterisation of occupant behaviour.

By applying homogeneous HMMs on the electricity consumption of fourteen apartments, three states describing the data were found suitable. The most likely sequence of states was determined (global decoding). From reconstruction of the states, dependencies like ambient air temperature were investigated. Combined with an occupant survey, this was used to classify/interpret the states as (1) absent or asleep, (2) home, medium consumption and (3) home, high consumption. From the global decoding, the average probability profiles with respect to time of day were investigated, and four distinct patterns of occupant behaviour were observed. Based on the initial results of the homogeneous HMMs and with the observed dependencies, time dependent HMMs (inhomogeneous HMMs) were developed, which improved forecasting. For both the homogeneous and inhomogeneous HMMs, indications of common parameters were observed, which suggests further development of the HMMs as population models.
Impact of Inter- and Intra-Regional Coordination in Markets With a Large Renewable Component

The establishment of the single European day-ahead market has accomplished a crucial step towards the spatial integration of the European power system. However, this new arrangement does not consider any intra-regional coordination of day-ahead and balancing markets and thus may become counterproductive or inefficient under uncertain supply, e.g., from weather-driven renewable power generation. In the absence of a specific target model for the common balancing market in Europe, we introduce a framework to compare different coordination schemes and market organizations. The proposed models are formulated as stochastic equilibrium problems and compared against an optimal market setup. The simulation results reveal significant efficiency loss in case of partial coordination and diversity of market structure among regional power systems.

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Scopus rating (2011): SJR 1.725 SNIP 3.254 CiteScore 5.34
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Impacts of urban development and climate change in exposing cities to pluvial flooding

Urban areas are characterized by very high concentrations of people and economic activities and are thus particularly vulnerable to flooding during extreme precipitation. Urban development and climate change are among the key drivers of changes in the exposure of cities to the occurrence and impacts of pluvial flooding. Cities are often dominated by large areas of impervious surfaces, that is, man-made sealed surfaces which water cannot penetrate, and increases in these – for example, as a consequence of urban development – can cause elevated run-off volumes and flood levels during precipitation. Climate change is expected to affect the intensity and frequency of extreme precipitation, with increases projected for many regions, including most parts of Europe.

General information
State: Published
Organisations: Department of Management Engineering, Systems Analysis, Department of Environmental Engineering, Urban Water Systems, Department of Applied Mathematics and Computer Science, Dynamical Systems
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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.

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Integration of large-scale heat pumps in the district heating systems of Greater Copenhagen
This study analyses the technical and private economic aspects of integrating a large capacity of electric driven HP (heat pumps) in the Greater Copenhagen DH (district heating) system, which is an example of a state-of-the-art large district heating system with many consumers and suppliers. The analysis was based on using the energy model Balmorel to determine the optimum dispatch of HPs in the system. The potential heat sources in Copenhagen for use in HPs were determined based on data related to temperatures, flows, and hydrography at different locations, while respecting technical constraints. The Balmorel model was developed further in order to provide a better representation of HPs, for analysing the seasonal variations of COP (Coefficient of Performance), and to represent the difference in performance of HPs connected to either distribution or transmission networks. The optimization yields roughly 3500 FLH (full load hours) for the HPs connected to the DH distribution networks when considering a current scenario. In a zero carbon-dioxide emission scenario expected in year 2025, approximately 4000 FLH, are achieved. In the case where HPs are connected to the DH transmission network at elevated temperatures, their operation decreases by roughly 1000 FLH. No significant impact was found when comparing fixed and varying operation characteristics of the HP.

General information
State: Published
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Large Steel Tank Fails and Rockets to Height of 30 meters - Rupture Disc Installed Incorrectly
At a brewery, the base plate-to-shell weld seam of a 90-m³ vertical cylindrical steel tank failed catastrophically. The 4 ton tank "took off" like a rocket leaving its contents behind, and landed on a van, crushing it. The top of the tank reached a height of 30 m. The internal overpressure responsible for the failure was an estimated 60 kPa. A rupture disc rated at <50 kPa provided overpressure protection and thus prevented the tank from being covered by the European Pressure Equipment Directive. This safeguard failed and it was later discovered that the rupture disc had been installed upside down. The organizational root cause of this incident may be a fundamental lack of appreciation of the hazards of large volumes of low-pressure compressed air or gas. A contributing factor may be that the standard piping and instrumentation diagram (P&ID) symbol for a rupture disc may confuse and lead to incorrect installation. Compressed air systems are ubiquitous. The medium is not toxic or flammable. Such systems however, when operated at "slight overpressure" can store a great deal of energy and thus constitute a hazard that ought to be addressed by safety managers.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Statistics and Data Analysis, COWI A/S
Authors: Hedlund, F. H. (Intern), Selig, R. S. (Ekstern), Kragh, E. K. (Ekstern)
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Learning from nature: Nature-inspired algorithms

During last decade, the nature has inspired researchers to develop new algorithms. The largest collection of nature-inspired algorithms is biology-inspired: swarm intelligence (particle swarm optimization, ant colony optimization, cuckoo search, bees' algorithm, bat algorithm, firefly algorithm etc.), genetic and evolutionary strategies, artificial immune systems etc. Well-known examples of applications include: aircraft wing design, wind turbine design, bionic car, bullet train, optimal decisions related to traffic, appropriate strategies to survive under a well-adapted immune system etc. Based on collective social behaviour of organisms, researchers have developed optimization strategies taking into account not only the individuals, but also groups and environment. However, learning from nature, new classes of approaches can be identified, tested and compared against already available algorithms. This work reviews the most effective nature-inspired algorithms and describes learning strategies based on nature oriented thinking. Examples and the benefits obtained from applying nature-inspired strategies in test generation, learners group optimization, and artificial immune systems for learning are given.

Load forecasting of supermarket refrigeration

This paper presents a novel study of models for forecasting the electrical load for supermarket refrigeration. The data used for building the models consists of load measurements, local climate measurements and weather forecasts. The load measurements are from a supermarket located in a village in Denmark. Every hour the hourly electrical load for refrigeration is forecasted for the following 42 h. The forecast models are adaptive linear time series models. The model has two regimes; one for opening hours and one for closing hours, this is modeled by a regime switching model and two
different methods for predicting the regimes are tested. The dynamic relation between the weather and the load is modeled by simple transfer functions and the non-linearities are described using spline functions. The results are thoroughly evaluated and it is shown that the spline functions are suitable for handling the non-linear relations and that after applying an auto-regressive noise model the one-step ahead residuals do not contain further significant information.

**General information**

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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Office for Study Programmes and Student Affairs, Centre for IT-Intelligent Energy Systems in Cities, Technical University of Denmark, ENFOR A/S, Danish Technological Institute, Danfoss A/S  
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Scopus rating (2016): CiteScore 7.78 SJR 3.058 SNIP 2.573  
Web of Science (2016): Indexed yes  
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Scopus rating (2015): SJR 2.912 SNIP 2.61 CiteScore 6.4  
Web of Science (2015): Indexed yes  
BFI (2014): BFI-level 2  
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Web of Science (2014): Indexed yes  
BFI (2013): BFI-level 1  
Scopus rating (2013): SJR 3.164 SNIP 3.377 CiteScore 6.59  
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Web of Science (2013): Indexed yes  
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ISI indexed (2011): ISI indexed yes  
Web of Science (2011): Indexed yes  
BFI (2010): BFI-level 1  
Scopus rating (2010): SJR 1.516 SNIP 2.25  
Web of Science (2010): Indexed yes  
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Scopus rating (2009): SJR 1.003 SNIP 1.781  
Web of Science (2009): Indexed yes  
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Scopus rating (2008): SJR 0.974 SNIP 1.215  
Web of Science (2008): Indexed yes  
Scopus rating (2007): SJR 1.179 SNIP 1.709
Long Memory of Financial Time Series and Hidden Markov Models with Time-Varying Parameters

Hidden Markov models are often used to model daily returns and to infer the hidden state of financial markets. Previous studies have found that the estimated models change over time, but the implications of the time-varying behavior have not been thoroughly examined. This paper presents an adaptive estimation approach that allows for the parameters of the estimated models to be time varying. It is shown that a two-state Gaussian hidden Markov model with time-varying parameters is able to reproduce the long memory of squared daily returns that was previously believed to be the most difficult fact to reproduce with a hidden Markov model. Capturing the time-varying behavior of the parameters also leads to improved one-step density forecasts. Finally, it is shown that the forecasting performance of the estimated models can be further improved using local smoothing to forecast the parameter variations.
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.

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.

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Scopus rating (2011): SJR 0.257 SNIP 0.312
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Scopus rating (2009): SJR 0.215 SNIP 0.296
Scopus rating (2008): SJR 0.125 SNIP 0.105
Scopus rating (2007): SJR 0.126 SNIP 0.065
Scopus rating (2006): SJR 0.101 SNIP 0.005
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Modeling and Control for Price Responsive Electricity Loads
This thesis deals with the development of model-based control architectures to facilitate renewable sources integration in the power system, focusing on residential buildings. Energy use in buildings in developed countries is increasing rapidly, and advanced model based techniques for control of thermal storages are becoming popular due to the high demand for solutions that improve energy efficiency and reduce operating costs.

This presents new challenges on how to integrate uncertain and intermittent energy sources. This work proposes methods for control of price responsive electricity loads in future energy systems and methods for handling stochasticity of, e.g., wind and solar power production. Hierarchies of aggregators and predictive controllers, in flexible demand side response, are implemented to achieve a balance with the non-dispatchable energy production.

Particular focus is given on producing models for control that facilitate better planning for an efficient integration of renewable energy into the power generation. Combining both data and statistical expertise, opens up new possibilities for designing models that describe thermal storages flexibility.
Finally, focus is also put on the problem of managing a virtual power plant equipped with stochastic energy sources and flexible consumers. Two distinct control approaches are described: direct control of the load consumption and indirect control by broadcasting a price signal. The advantages and challenges of these two approaches are discussed providing examples for suggested techniques.

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**Modeling and Prediction Using Stochastic Differential Equations**
Pharmacokinetic/pharmakodynamic (PK/PD) modeling for a single subject is most often performed using nonlinear models based on deterministic ordinary differential equations (ODEs), and the variation between subjects in a population of subjects is described using a population (mixed effects) setup that describes the variation between subjects. The ODE setup implies that the variation for a single subject is described by a single parameter (or vector), namely the variance (covariance) of the residuals. Furthermore the prediction of the states is given as the solution to the ODEs and hence assumed deterministic and can predict the future perfectly. A more realistic approach would be to allow for randomness in the model due to e.g., the model be too simple or errors in input. We describe a modeling and prediction setup which better reflects reality and suggests stochastic differential equations (SDEs) for modeling and forecasting. It is argued that this gives models and predictions which better reflect reality. The SDE approach also offers a more adequate framework for modeling and a number of efficient tools for model building. A software package (CTSM-R) for SDE-based modeling is briefly described.

**General information**
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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Copenhagen Center for Health Technology, Center for Energy Resources Engineering, Scientific Computing
Authors: Juhl, R. (Intern), Møller, J. K. (Intern), Jørgensen, J. B. (Intern), Madsen, H. (Intern)
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Modeling the growth dynamics of multiple Escherichia coli strains in the pig intestine following intramuscular ampicillin treatment

**Background:** This study evaluated how dosing regimen for intramuscularly-administered ampicillin, composition of Escherichia coli strains with regard to ampicillin susceptibility, and excretion of bacteria from the intestine affected the level of resistance among Escherichia coli strains in the intestine of nursery pigs. It also examined the dynamics of the composition of bacterial strains during and after the treatment. The growth responses of strains to ampicillin concentrations were determined using in vitro growth curves. Using these results as input data, growth predictions were generated using a mathematical model to simulate the competitive growth of E. coli strains in a pig intestine under specified plasma concentration profiles of ampicillin.

**Results:** In vitro growth results demonstrated that the resistant strains did not carry a fitness cost for their resistance, and that the most susceptible strains were more affected by increasing concentrations of antibiotics that the rest of the strains. The modeling revealed that short treatment duration resulted in lower levels of resistance and that dosing frequency did not substantially influence the growth of resistant strains. Resistance levels were found to be sensitive to the number of competing strains, and this effect was enhanced by longer duration of treatment. High excretion of bacteria from the intestine favored resistant strains over sensitive strains, but at the same time it resulted in a faster return to pre-treatment levels after the treatment ended. When the duration of high excretion was set to be limited to the treatment time (i.e. the treatment was assumed to result in a cure of diarrhea) resistant strains required longer time to reach the previous level.

**Conclusion:** No fitness cost was found to be associated with ampicillin resistance in E. coli. Besides dosing factors, epidemiological factors (such as number of competing strains and bacterial excretion) influenced resistance development and need to be considered further in relation to optimal treatment strategies. The modeling approach used in the study is generic, and could be used for prediction of the effect of treatment with other drugs and other administration routes for effect on resistance development in the intestine of pigs.

**General information**

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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, National Veterinary Institute, Section for Epidemiology, University of Copenhagen, University of Glasgow
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Modelling of glucose-insulin-glucagon pharmacodynamics in man
The purpose is to build a simulation model of the glucoregulatory system in man. We estimate individual human parameters of a physiological glucose-insulin-glucagon model. We report posterior probability distributions and correlations of model parameters.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Zealand Pharma A/S, McGill University
Authors: Wendt, S. L. (Intern), Møller, J. K. (Intern), Haidar, A. (Ekstern), Knudsen, C. B. (Ekstern), Madsen, H. (Intern), Jørgensen, J. B. (Intern)
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Modelling the glucose-insulin-glucagon dynamics after subcutaneous administration of native glucagon and a novel glucagon analogue in dogs
Zealand Pharma has invented a glucagon analogue, ZP-GA-1, with increased stability in liquid formulation for treatment of hypoglycemia. A pharmacodynamic (PD) model is needed to compare ZP-GA-1 with marketed glucagon. We aim to develop a model of the complex glucose-insulin-glucagon dynamics based on physiology and data.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Copenhagen Center for Health Technology, Center for Energy Resources Engineering, Dynamical Systems, Zealand Pharma A/S, McGill University
Authors: Wendt, S. L. (Intern), Boye Knudsen, C. (Ekstern), Jørgensen, J. B. (Intern), Madsen, H. (Intern), Haidar, A. (Ekstern)
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Modelling the glucose-insulin-glucagon dynamics after subcutaneous administration of native glucagon and a novel glucagon analogue in dogs
In healthy individuals, insulin and glucagon work in a complex fashion to maintain blood glucose levels within a narrow range. This regulation is distorted in patients with diabetes. The hepatic glucose response due to an elevated glucagon level depends on the current insulin concentration and thus endogenous glucose production (EGP) can not be modelled without knowledge of the concentration of both hormones in plasma. Furthermore, literature suggests an upper limit to EGP irrespective of glucagon levels. We build a simulation model of the glucose-insulin-glucagon

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Copenhagen Center for Health Technology, Center for Energy Resources Engineering, Dynamical Systems, Zealand Pharma A/S, McGill University
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Number of pages: 1
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Model of the Glucose-Insulin-Glucagon Dynamics after Subcutaneous Administration of a Glucagon Rescue Bolus in Healthy Humans
In healthy individuals, insulin and glucagon work in a complex fashion to maintain blood glucose levels within a narrow range. This regulation is distorted in patients with diabetes. The hepatic glucose response due to an elevated glucagon level depends on the current insulin concentration and thus endogenous glucose production (EGP) can not be modelled without knowledge of the concentration of both hormones in plasma. Furthermore, literature suggests an upper limit to EGP irrespective of glucagon levels. We build a simulation model of the glucose-insulin-glucagon
dynamics in man including saturation effect of EGP.

Ten healthy subjects received a 1 mg subcutaneous (SC) glucagon bolus (GlucaGen®). Plasma samples were collected until 300 minutes post dose and analyzed for glucagon, insulin, and glucose concentrations. All observations were used to fit a physiological model of the glucose-insulin-glucagon dynamics using the Hovorka model with a novel multiplicative description of the effects of insulin and of glucagon on EGP.

Bayesian estimation by Maximum a Posteriori using prior knowledge reported in literature was used to estimate the model parameters for each subject. Profile likelihood plots were used to investigate parameter identifiability. Unidentifiable parameters were fixed at their prior mean values.

The new model enables simulations of the glucose-insulin-glucagon dynamics in humans at both low and high glucagon concentrations (180-8000 pg/mL) and physiologic insulin concentrations (1.2-81.9 mIU/L). The model can be used for simulation of glucagon bolus strategies for treatment of hypoglycemia and for in silico simulation of dual-hormone artificial pancreas algorithms.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Copenhagen Center for Health Technology, Center for Energy Resources Engineering, Zealand Pharma A/S, McGill University
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Model of the Glucose-Insulin-Glucagon Dynamics after Subcutaneous Administration of a Glucagon Rescue Bolus in Healthy Humans
In healthy individuals, insulin and glucagon work in a complex fashion to maintain blood glucose levels within a narrow range. This regulation is distorted in patients with diabetes. The hepatic glucose response due to an elevated glucagon level depends on the current insulin concentration and thus endogenous glucose production (EGP) cannot be modelled without knowledge of the concentration of both hormones in plasma. Furthermore, literature suggests an upper limit to EGP irrespective of glucagon levels. We build a simulation model of the glucose-insulin-glucagon dynamics in man including saturation effect of EGP.

Ten healthy subjects received a 1 mg subcutaneous (SC) glucagon bolus (GlucaGen®). Plasma samples were collected until 300 minutes post dose and analyzed for glucagon, insulin, and glucose concentrations. All observations were used to fit a physiological model of the glucose-insulin-glucagon dynamics using the Hovorka model with a novel multiplicative description of the effects of insulin and of glucagon on EGP.

Bayesian estimation by Maximum a Posteriori using prior knowledge reported in literature was used to estimate the model parameters for each subject. Profile likelihood plots were used to investigate parameter identifiability. Unidentifiable parameters were fixed at their prior mean values.

The new model enables simulations of the glucose-insulin-glucagon dynamics in humans at both low and high glucagon concentrations (180-8000 pg/mL) and physiologic insulin concentrations (1.2-81.9 mIU/L). The model can be used for simulation of glucagon bolus strategies for treatment of hypoglycemia and for in silico simulation of dual-hormone artificial pancreas algorithms.
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.
Models to Estimate Lactation Curves of Milk Yield and Somatic Cell Count in Dairy Cows at the Herd Level for the Use in Simulations and Predictive Models

Typically, central milk recording data from dairy herds are recorded less than monthly. Over-fitting early in lactation periods is a challenge, which we explored in different ways by reducing the number of parameters needed to describe the milk yield and somatic cell count of individual cows. Furthermore, we investigated how the parameters of lactation models correlate between parities and from dam to offspring. The aim of the study was to provide simple and robust models for cow level milk yield and somatic cell count for fitting to sparse data to parameterize herd- and cow-specific simulation of dairy herds. Data from 610 Danish Holstein herds were used to determine parity traits in milk production regarding milk yield and somatic cell count of individual cows. Parity was stratified in first, second, and third and higher for milk, and first to sixth and higher for somatic cell count. Fitting of herd level parameters allowed for cow level lactation curves with three, two, or one parameters per lactation. Correlations of milk yield and somatic cell count were estimated between lactations and between dam and offspring. The shape of the lactation curves varied markedly between farms. The correlation between lactations for milk yield and somatic cell count was 0.2–0.6 and significant on more than 95% of farms. The variation in the daily milk yield was observed to be a source of variation to the somatic cell count, and the total somatic cell count was less correlated with the milk production than somatic cells per milliliter. A positive correlation was found between relative levels of the total somatic cell count and the milk yield. The variation of lactation and somatic cell count curves between farms highlights the importance of a herd level approach. The one-parameter per cow model using a herd level curve allows for estimating the cow production level from first the recording in the parity, while a two-parameter model requires more recordings for a credible estimate, but may more precisely predict persistence, and given the independence of parameters, these can be easily drawn for use in simulation models. We also conclude that using total somatic cell count may stabilize models, and therefore, the dilution factor is of importance in Danish Holstein.
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.

Multistrain models predict sequential multidrug treatment strategies to result in less antimicrobial resistance than combination treatment
Background: Combination treatment is increasingly used to fight infections caused by bacteria resistant to two or more antimicrobials. While multiple studies have evaluated treatment strategies to minimize the emergence of resistant strains for single antimicrobial treatment, fewer studies have considered combination treatments. The current study modeled bacterial growth in the intestine of pigs after intramuscular combination treatment (i.e. using two antibiotics simultaneously) and sequential treatments (i.e. alternating between two antibiotics) in order to identify the factors that favor the sensitive fraction of the commensal flora. Growth parameters for competing bacterial strains were estimated from the combined in vitro pharmacodynamic effect of two antimicrobials using the relationship between concentration and net bacterial growth rate. Predictions of in vivo bacterial growth were generated by a mathematical model of the competitive growth of multiple strains of Escherichia coli. Results: Simulation studies showed that sequential use of tetracycline and ampicillin reduced the level of double resistance, when compared to the combination treatment. The effect of the cycling frequency (how frequently antibiotics are alternated in a sequential treatment) of the two drugs was dependent upon the order in which the two drugs were used. Conclusion: Sequential treatment was more effective in preventing the growth of resistant strains when compared to the combination treatment. The cycling frequency did not play a role in suppressing the growth of resistant strains, but the specific order of the two antimicrobials did. Predictions made from the study could be used to redesign multidrug treatment strategies not only for intramuscular treatment in pigs, but also for other dosing routes.
Non-parametric method for separating domestic hot water heating spikes and space heating

In this paper a method for separating spikes from a noisy data series, where the data change and evolve over time, is presented. The method is applied on measurements of the total heat load for a single family house. It relies on the fact that the domestic hot water heating is a process generating short-lived spikes in the time series, while the space heating changes in slower patterns during the day dependent on the climate and user behavior. The challenge is to separate the domestic hot water heating spikes from the space heating without affecting the natural noise in the space heating measurements. The assumption behind the developed method is that the space heating can be estimated by a non-parametric kernel smoother, such that every value significantly above this kernel smoother estimate is identified as a domestic hot water heating spike. First, it is showed how a basic kernel smoothing approach is too simple to deliver reliable results. Therefore the problem is generalized to a local least squares problem, which makes it possible to design a robust kernel smoother, which estimate is not affected by the spikes. Furthermore, the generalized model makes it possible to estimate higher order local polynomials. Finally, the results are evaluated and it is found that the method is capable of calculating a reliable separation of the total heat load into the two components.
Objective Classification of Rainfall in Northern Europe for Online Operation of Urban Water Systems Based on Clustering Techniques

This study evaluated methods for automated classification of rain events into groups of "high" and "low" spatial and temporal variability in offline and online situations. The applied classification techniques are fast and based on rainfall data only, and can thus be applied by, e.g., water system operators to change modes of control of their facilities. A k-means clustering technique was applied to group events retrospectively and was able to distinguish events with clearly different temporal and spatial correlation properties. For online applications, techniques based on k-means clustering and quadratic discriminant analysis both provided a fast and reliable identification of rain events of "high" variability, while the k-means provided the smallest number of rain events falsely identified as being of "high" variability (false hits). A simple classification method based on a threshold for the observed rainfall intensity yielded a large number of false hits and was thus outperformed by the other two methods.

General information
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Organisations: Department of Environmental Engineering, Urban Water Systems, Department of Applied Mathematics and Computer Science, Dynamical Systems, University of Oxford
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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.

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Oscillating nonlinear acoustic shock waves
We investigate oscillating shock waves in a tube using a higher order weakly nonlinear acoustic model. The model includes thermoviscous effects and is non isentropic. The oscillating shock waves are generated at one end of the tube by a sinusoidal driver. Numerical simulations show that at resonance a stationary state arise consisting of multiple oscillating shock waves. Off resonance driving leads to a nearly linear oscillating ground state but superimposed by bursts of a fast oscillating shock wave. Based on a travelling wave ansatz for the fluid velocity potential with an added 2'nd order polynomial in the space and time variables, we find analytical approximations to the observed single shock waves in an infinitely long tube. Using perturbation theory for the driven acoustic system approximative analytical solutions for the off resonant case are determined.

Pattern formation in annular systems of repulsive particles
General particle models with symmetric and asymmetric repulsion are studied and investigated for finite-range and exponential interaction in an annulus. In the symmetric case transitions from one- to multi-lane behavior including multistability are observed for varying particle density and for a varying curvature with fixed density. Hence, the system cannot be approximated by a periodic channel. In the asymmetric case, which is important in pedestrian dynamics, we reveal an inhomogeneous new phase, a traveling wave reminiscent of peristaltic motion.
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Web of Science (2015): Indexed yes
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ISI indexed (2011): ISI indexed yes
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Scopus rating (2008): SJR 1.057 SNIP 1.109
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Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.883 SNIP 1.02
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 0.898 SNIP 0.988
Web of Science (2004): Indexed yes
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Web of Science (2003): Indexed yes
PK/PD modelling of glucose-insulin-glucagon dynamics in healthy dogs after a subcutaneous bolus administration of native glucagon or a novel glucagon analogue

**Objective** We aim to develop a simulation model of the complex glucose-insulin-glucagon dynamics based on physiology and data. Furthermore, we compare pharmacokinetic (PK) and pharmacodynamic (PD) characteristics of marketed reconstituted glucagon with a stable liquid glucagon analogue invented by Zealand Pharma A/S.

**Research Design and Methods** We expanded a physiological model of endogenous glucose production with multiplicative effects of insulin and glucagon and combined it with the Hovorka glucoregulatory model. We used a Bayesian framework to perform multidimensional MAP estimation of model parameters given priors reported in the literature. We used profile likelihood analysis to investigate parameter identifiability and reduce the number of model variables. We estimated model parameters in pre-clinical data from one cross-over study with a total of 20 experiments in five dogs. The dogs received two subcutaneous (SC) bolus injections of low and high doses of glucagon and ZP-GA-1 (20 and 120 nmol/kg).

**Results** We report posterior probability distributions and correlations for all identifiable model parameters. Based on visual inspection and residual analysis, the PD model described data satisfactorily for both glucagon and the analogue. Parameter estimates of the PD model were not significantly different between the two compounds.

**Conclusions** The new PK/PD model enables simulations of the glucose-insulin-glucagon dynamics after a SC bolus of glucagon or glucagon analogue. The novel glucagon analogue by Zealand Pharma A/S shows PK and PD characteristics similar to marketed glucagon.
Possible Power Estimation of Down-Regulated Offshore Wind Power Plants.
The penetration of offshore wind power is continuously increasing in the Northern European grids. To assure safety in the operation of the power system, wind power plants are required to provide ancillary services, including reserve power attained through down-regulating the wind farm from its maximum possible power. Currently, there is neither a standardised regulation by the TSOs nor a verified approach regarding the wind farm scale available power estimation. Here we describe an industrially applicable, validated method for the real-time estimation of the possible power of an offshore wind power plant. The developed procedure, the PossPOW algorithm, can also be used in the wind farm control as it yields a real-time wind farm power curve. The modern wind turbines have a possible power signal at the turbine level and the current state of the art is to aggregate those signals to achieve the wind farm scale production capacity. However the summation of these individual signals is simply an over-estimation for the wind power plant, due to reduced wake losses during curtailment. The determination of the possible power with the PossPOW algorithm works as follows: firstly the second-wise upstream wind speed is estimated, since it is not affected by any wake. Then the upstream wind is introduced into the wake model, adjusted for the same time resolution, to simulate the power losses that would occur during nominal operation. The PossPOW algorithm uses only 1 Hz turbine data as inputs, namely power, pitch angle, and rotational speed. The method is validated in Horns Rev-I, Lillgrund and Thanet offshore wind farms, together with NREL 5MW simulations. The reduced wake is replaced by the wake model which estimates the velocity deficit for nominal operation. An evaluation of the existing wake models show that the suitable models are tuned for 10-min averaged data. Therefore, the Larsen wake model is re-calibrated for real-time using Thanet data, validated in Horns Rev-I and then implemented in farm scale considering the local turbulence, time delay and meandering. The validation of the algorithm is performed using experiments in Horns Rev-I where two of the upstream turbines are curtailed. The PossPOW algorithm is compared to the current practice and shown to perform significantly better, according to the error scores stipulated in the Danish grid code.

General information
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Probabilistic Approaches to Energy Systems
Energy generation from wind and sun is increasing rapidly in many parts of the world. This presents new challenges on how to integrate this uncertain, intermittent and non-dispatchable energy source. This thesis deals with forecasting and decision making in energy systems with a large proportion of renewable energy generation. Particularly we focus on producing forecasting models that can predict renewable energy generation, single user demand, and provide advanced forecast products that are needed for an efficient integration of renewable energy into the power generation mix. Such forecasts can be useful on all levels of the energy systems, ranging from the highest level, where the transmission system operator is concerned with minimizing system failures and is aided by wind power forecasts, to the end user of energy where power price forecasts are useful for users with flexible power demand.

The main contributions of this thesis lie in the realm of using gray box models to produce forecasts for energy systems. Gray box models can be defined as a crossover between physical models (or white box models), that base their model on a physical understanding of the system at hand, and data driven models (or black box models) that focus on accurately describing the data without considering physical limitations of the system. Integrating these physical structures into a data driven approach allows for producing better forecasts with more accurate predictions. In this thesis we have developed and applied methodologies for gray box modeling to produce forecasts for vehicle driving patterns, solar irradiance, wind speeds, wind power, and solar power. The model for driving patterns has subsequently been used as input into an optimization algorithm for charging a single electric vehicle. In a subsequent study the behavior of a fleet of electric vehicles has been studied.

In the thesis we go through various examples of forecasts products and their applications. We emphasize that forecasting can not stand alone and should be complimented by optimization and decision making tools for an efficient integration of renewable energy. Thus forecast products should be developed in unison with the decision making tool as they are two
sides of the same overall challenge.

Probabilistic forecasting of the solar irradiance with recursive ARMA and GARCH models
Forecasting of the solar irradiance is a key feature in order to increase the penetration rate of solar energy into the energy grids. Indeed, the anticipation of the fluctuations of the solar renewables allows a better management of the production means of electricity and a better operation of the grid-connected storage systems. If numerous methods for forecasting the mean of the solar irradiance were recently developed, there are only few works dedicated to the evaluation of prediction intervals associated to these point forecasts.

Time series of solar irradiance and more specifically of clear sky index show some similarities with that of financial time series. The aim of this paper is to assess the performances of a commonly used combination of two linear models (ARMA and GARCH) in econometrics in order to provide probabilistic forecasts of solar irradiance. In addition, a recursive estimation of the parameters of the models has been set up in order to provide a framework that can be applied easily in an operational context.

A comprehensive testing procedure has been used to assess both point forecasts and probabilistic forecasts. Using only the past records of the solar irradiance, the proposed model is able to perform point forecasts as accurately as other methods based on machine learning techniques. Moreover, the recursive ARMA-GARCH model is easier to set-up and it gives additional information about the uncertainty of the forecasts. Even if some strong assumption has been made regarding the statistical distribution of the error, the reliability of the probabilistic forecasts stands in the same order of magnitude as other works done in the field of solar forecasting.
Probabilistic Forecasts of Wind Power Generation by Stochastic Differential Equation Models

The increasing penetration of wind power has resulted in larger shares of volatile sources of supply in power systems worldwide. In order to operate such systems efficiently, methods for reliable probabilistic forecasts of future wind power production are essential. It is well known that the conditional density of wind power production is highly dependent on the
level of predicted wind power and prediction horizon. This paper describes a new approach for wind power forecasting based on logistic-type stochastic differential equations (SDEs). The SDE formulation allows us to calculate both state-dependent conditional uncertainties as well as correlation structures. Model estimation is performed by maximizing the likelihood of a multidimensional random vector while accounting for the correlation structure defined by the SDE formulation. We use non-parametric modelling to explore conditional correlation structures, and skewness of the predictive distributions as a function of explanatory variables.

**General information**
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Møller, J. K. (Intern), Zugno, M. (Intern), Madsen, H. (Intern)
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Main Research Area: Technical/natural sciences

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Web of Science (2017): Indexed Yes
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Scopus rating (2016): CiteScore 0.99 SJR 0.615 SNIP 0.925
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.763 SNIP 0.74 CiteScore 1.03
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.542 SNIP 0.904 CiteScore 0.98
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.844 SNIP 1.453 CiteScore 1.26
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.618 SNIP 1.14 CiteScore 1.03
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.033 SNIP 1.026 CiteScore 1.19
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.66 SNIP 0.83
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.506 SNIP 1.046
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.485 SNIP 1.117
Scopus rating (2007): SJR 0.43 SNIP 0.713
Scopus rating (2006): SJR 0.471 SNIP 0.998
Scopus rating (2005): SJR 0.645 SNIP 1.049
Scopus rating (2004): SJR 0.449 SNIP 0.856
Scopus rating (2003): SJR 0.961 SNIP 1.138
Scopus rating (2002): SJR 0.544 SNIP 1.015
Scopus rating (2001): SJR 0.913 SNIP 1.184
Scopus rating (2000): SJR 0.475 SNIP 0.572
Scopus rating (1999): SJR 0.319 SNIP 0.604
Probabilistic runoff volume forecasting in risk-based optimization for RTC of urban drainage systems

This article demonstrates the incorporation of stochastic grey-box models for urban runoff forecasting into a full-scale, system-wide control setup where setpoints are dynamically optimized considering forecast uncertainty and sensitivity of overflow locations in order to reduce combined sewer overflow risk. The stochastic control framework and the performance of the runoff forecasting models are tested in a case study in Copenhagen (76 km² with 6 sub-catchments and 7 control points) using 2-h radar rainfall forecasts and inlet flows to control points computed from a variety of noisy/oscillating in-sewer measurements. Radar rainfall forecasts as model inputs yield considerably lower runoff forecast skills than “perfect” gauge-based rainfall observations (ex-post hindcasting). Nevertheless, the stochastic grey-box models clearly outperform benchmark forecast models based on exponential smoothing. Simulations demonstrate notable improvements of the control efficiency when considering forecast information and additionally when considering forecast uncertainty, compared with optimization based on current basin fillings only.
Probing NWP model deficiencies by statistical postprocessing

The objective in this article is twofold. On one hand, a Model Output Statistics (MOS) framework for improved wind speed forecast accuracy is described and evaluated. On the other hand, the approach explored identifies unintuitive explanatory value from a diagnostic variable in an operational numerical weather prediction (NWP) model generating global weather forecasts four times daily, with numerous users worldwide. The analysis is based on two years of hourly wind speed time series measured at three locations; offshore, in coastal and flat terrain, and inland in complex topography, respectively. Based on the statistical model candidates inferred from the data, the lifted index NWP model diagnostic is consistently found among the NWP model predictors of the best performing statistical models across sites.

General information

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Wind Energy, Meteorology, ENFOR A/S
Authors: Rosgaard, M. H. (Intern), Nielsen, H. A. (Ekstern), Nielsen, T. S. (Ekstern), Hahmann, A. N. (Intern)
Pages: 1017–1028
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information

Journal: Quarterly Journal of the Royal Meteorological Society
Volume: 142
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ISSN (Print): 0035-9009
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Web of Science (2017): Indexed Yes
Real-Time Procurement Strategies of a Proactive Distribution Company with Aggregator-Based Demand Response

In this paper, we present a real-time trading framework for distribution networks where a rational aggregator is identified as a broker by contracting with individual demands and dealing with the distribution company. Demand response capability is characterized by the coexistence of elastic and inelastic demand components. A one-leader multi-follower bilevel model is proposed to derive the procurement strategies, i.e., the upper-level problem intends to maximize the profit of the proactive distribution company, while the lower-level expresses the profit maximization per rational aggregator. The
proposed model is then transformed into a solvable mathematical program with equilibrium constraints through a primal-dual approach. A modified 33-bus distribution network is utilized to demonstrate the effectiveness of the proposed model.

**General information**
State: E-pub ahead of print
Organizations: Department of Electrical Engineering, Center for Electric Power and Energy, Energy Analytics and Markets, Department of Applied Mathematics and Computer Science, Dynamical Systems, Argonne National Laboratory
Authors: Zhang, C. (Intern), Wang, Q. (Intern), Wang, J. (Ekstern), Pinson, P. (Intern), Morales González, J. M. (Intern), Østergaard, J. (Intern)
Number of pages: 11
Publication date: 2016
Main Research Area: Technical/natural sciences

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Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 7.73 SJR 2.851 SNIP 2.58
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 3.785 SNIP 3.424 CiteScore 8.48
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 3.105 SNIP 3.799 CiteScore 7.77
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 3.175 SNIP 4.831 CiteScore 9.88
ISI indexed (2013): ISI indexed no
Web of Science (2013): Indexed yes
Scopus rating (2012): SJR 2.023 SNIP 6.821 CiteScore 13.33
ISI indexed (2012): ISI indexed no
Web of Science (2012): Indexed yes
Scopus rating (2011): SJR 0.902 SNIP 6.022 CiteScore 11.78
ISI indexed (2011): ISI indexed no
Web of Science (2011): Indexed yes
Original language: English

Real-time Trading Strategies for Proactive Distribution Company with Distributed Generation and Demand Response. Distributed energy resources (DERs), such as distributed generation (DG) and demand response (DR), have been recognized worldwide as valuable resources. High integration of DG and DR in the distribution network inspires a potential deregulated environment for the distribution company (DISCO) directly procuring capacities from local DG and DR. In this situation, a hierarchical market structure is achieved comprising the transmission-level (TL) and distribution-level (DL) markets. Focusing on the real-time process, as the interface actor, the DISCO’s behavior covers downwardly procuring DL DG and DR resources, and upwardly trading in the TL real-time market, resulting in a proactive manner.

The DL aggregator (DA) is defined to manage these small-scale and dispersed DGs and DRs. A methodology is proposed in this thesis for a proactive DISCO (PDISCO) to strategically trade with DAs in the presented DL market and transact with
A one-leader multi-follower-type bi-level model is proposed to indicate the PDISCO's trading strategies. To participate in the TL real-time market, a methodology is presented to derive continuous bidding/offering strategies for a PDISCO. A bi-level model is proposed to elaborate the interactions between the PDISCO's bids/offers and the TL market's outcomes. The PDISCO's trading performance features in a bidirectional transaction. In this thesis, replacing the lower-level problems with the primal-dual approach, each proposed bi-level model is transformed into a solvable single-level mathematical program with equilibrium constraints (MPEC). The effectiveness of the proposed models are verified by individual case studies.

Short-term Probabilistic Forecasting of Wind Speed Using Stochastic Differential Equations

It is widely accepted today that probabilistic forecasts of wind power production constitute valuable information for both wind power producers and power system operators to economically exploit this form of renewable energy, while mitigating the potential adverse effects related to its variable and uncertain nature. In this paper, we propose a modeling framework for wind speed that is based on stochastic differential equations. We show that stochastic differential equations allow us to naturally capture the time dependence structure of wind speed prediction errors (from 1 up to 24 hours ahead) and, most importantly, to derive point and quantile forecasts, predictive distributions, and time-path trajectories (also referred to as scenarios or ensemble forecasts), all by one single stochastic differential equation model characterized by a few parameters.
Simulating the Epidemiological and Economic Impact of Paratuberculosis Control Actions in Dairy Cattle

We describe a new mechanistic bioeconomic model for simulating the spread of Mycobacterium avium subsp. paratuberculosis (MAP) within a dairy cattle herd. The model includes age-dependent susceptibility for infection; age-dependent sensitivity for detection; environmental MAP build up in five separate areas of the farm; in utero infection; infection via colostrum and waste milk, and it allows for realistic culling (i.e., due to other diseases) by including a ranking system. We calibrated the model using a unique dataset from Denmark, including 102 random farms with no control actions against spread of MAP. Likewise, four control actions recommended in the Danish MAP control program were implemented in the model based on reported management strategies in Danish dairy herds in a MAP control scheme. We tested the model parameterization in a sensitivity analysis. We show that a test-and-cull strategy is on average the most cost-effective solution to decrease the prevalence and increase the total net revenue on a farm with low hygiene, but not more profitable than no control strategy on a farm with average hygiene. Although it is possible to eradicate MAP from the farm by implementing all four control actions from the Danish MAP control program, it was not economically attractive since the expenses for the control actions outweigh the benefits. Furthermore, the three most popular control actions against the spread of MAP on the farm were found to be costly and inefficient in lowering the prevalence when used independently.

General information
State: Published
Organisations: National Veterinary Institute, Section for Epidemiology, Department of Applied Mathematics and Computer Science, Dynamical Systems, University of Copenhagen, SEGES Cattle
Authors: Kirkeby, C. T. (Intern), Græsbøll, K. (Intern), Nielsen, S. S. (Ekstern), Christiansen, L. E. (Intern), Toft, N. (Intern), Rattenborg, E. (Ekstern), Hisham Beshara Halasa, T. (Intern)
Number of pages: 13
Publication date: 2016
Main Research Area: Technical/natural sciences

The Smart-Energy Operating-System (SE-OS) framework has been developed within the CITIES research project (www.smart-cities-centre.org). This framework enables a systematic approach for implementing flexible electric energy systems in smart cities. The SE-OS methodologies are based on methods for data analytics, cyber physical modelling, forecasting, control, optimization, IoT, IoS, and cloud computing. The SE-OS concept has been used for enabling flexibility and demand response in smart cities in a large number of demo projects. Finally, it is shown that SE-OS in combination with methods for energy systems (gas, thermal, power, biomass, fuel) integration can provide virtual energy storage solutions on all relevant time scales, i.e. from minutes to seasonal storage.

The Smart-Energy Operating-System (SE-OS) is used to develop, implement and test solutions (layers: data, models, optimization, control, communication) for operating flexible electrical energy systems at all scales.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Madsen, H. (Intern), Parvizi, J. (Intern), Bacher, P. (Intern)
Number of pages: 1
Publication date: 2016
Main Research Area: Technical/natural sciences
Links:
http://www.sustain.dtu.dk/

Bibliographical note
Sustain Abstract L-1
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2016

Smoothing a Piecewise-Smooth: An Example from Plankton Population Dynamics

In this work we discuss a piecewise-smooth dynamical system inspired by plankton observations and constructed for one predator switching its diet between two different types of prey. We then discuss two smooth formulations of the piecewise-smooth model obtained by using a hyperbolic tangent function and adding a dimension to the system. We compare model behaviour of the three systems and show an example case where the steepness of the switch is determined from a comparison with data on freshwater plankton.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Piltz, S. H. (Intern)
Pages: 147-151
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Publisher: Springer
ISBN (Print): 9783319556413
Statistical modelling using CTSM-R

The ability to forecast the future of a system is more important than ever. Countless of applications require precise forecasting models to make smarter decisions in real time. Practitioners need software tools allowing an easy, quick and accurate implementation of their ideas. This thesis shows our software CTSM-R, which means: Continuous Time Stochastic Modelling in R. CTSM-R provides the ability to implement statistical models and estimate unknown parameters. Thus allows modellers to model and understand the physical system of interest.

The main contributions of this thesis are the development of a generic software tool for grey box modelling. Grey box models use knowledge about the physical system of interest in combination with data to create models that accurately explain the data. The thesis will demonstrate how to implement linear and nonlinear models. These two model classes then serve as a building block for population models and spatiotemporal models. Population models known from the pharmaceutical industry where nonlinear population modelling has been long used in the industry to analyse trial data from many subjects. Spatiotemporal modelling extends CTSM-R to model complex correlations in space and time. This thesis demonstrates how to use spatio-temporal models for solar power forecasting.

CTSM-R is built in R using fast computations in Fortran when needed. CTSM-R provides a simple interface which is quickly learned through our examples on our website http://ctsm.info.

Finally, this thesis demonstrates the importance of identifiability. A model is just a representation of the physical reality and such a representation is not guaranteed to be unique. Identifiability and the use of profile likelihood figures should be a standard tool of any modeller to verify the uniqueness of the solution.
Surplus yeast tank failing catastrophically
GOOD REASON FOR CAUTION I A large surplus yeast tank shot into the air leaving the floor plate and the contents behind. Although not designed for overpressure, the tank was kept at "very slight overpressure" to suppress nuisance foaming. The brewery was unaware of the hazards of compressed air. The accident described in this article serves to illustrate that care should be taken if a tank originally designed for atmospheric pressure is modified to operate at slight overpressure.

The dynamics of magnetic vortices in type II superconductors with pinning sites studied by the time dependent Ginzburg–Landau model
We investigate the dynamics of magnetic vortices in type II superconductors with normal state pinning sites using the Ginzburg–Landau equations. Simulation results demonstrate hopping of vortices between pinning sites, influenced by external magnetic fields and external currents. The system is highly nonlinear and the vortices show complex nonlinear dynamical behaviour.
Thermal properties of Fiber ropes

There is a trend within the oil and gas market to shift from steel wire ropes to fiber ropes for lifting, hoisting and mooring applications. The cost of fiber ropes is about 2-3 times that of steel wire ropes, but the natural buoyancy of fiber ropes reduces the overall weight resulting in smaller cranes and thereby reduces the overall costs. For heave compensation, a rope is typically of 3-4000 meters long, such that one rope costs in the order of 7.5 million dollars. The current practice on when to discard a fiber rope is through visual inspections done manually with large safety factors. This means that the rope is discarded before it is necessary, increasing the overall life-cycle costs. The offshore industry wants a better monitoring system to understand when the fiber rope must be replaced.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Center for Intelligent Drug Delivery and Sensing Using Microcontainers and Nanomechanics, Technical University of Denmark, University of Southern Denmark
Authors: Bossolini, E. (Intern), Nielsen, O. W. (Ekstern), Oland, E. (Ekstern), Sørensen, M. P. (Intern), Veje, C. (Ekstern)
Number of pages: 4
Publication date: 2016
Main Research Area: Technical/natural sciences
Electronic versions:
teknova.pdf
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Publication: Research - peer-review › Paper – Annual report year: 2017

Tolerance of continuous NFT spectrum to the optical fiber channel impairments

The impact of launch power, additive white Gaussian noise and fiber loss on the nonlinear Fourier transform (NFT) continuous spectrum is investigated. NFT is shown to undergo lower spectral distortion than the discrete Fourier transform.

General information
State: Published
Organisations: Department of Photonics Engineering, High-Speed Optical Communication, Centre of Excellence for Silicon Photonics for Optical Communications, Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Gaiarin, S. (Intern), Da Ros, F. (Intern), Sørensen, M. P. (Intern), Zibar, D. (Intern)
Number of pages: 3
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Article number: SpM3E.5
ISBN (Print): 978-1-943580-14-9
Main Research Area: Technical/natural sciences
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gaiarin_sppcom2016_v2.pdf
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.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Copenhagen Center for Health Technology, Center for Energy Resources Engineering, Technical University of Denmark
Authors: Boiroux, D. (Intern), Aradóttir, T. B. (Ekstern), Hagdrup, M. (Intern), Poulsen, N. K. (Intern), Madsen, H. (Intern), Jørgensen, J. B. (Intern)
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Conference: 9th IFAC Symposium on Biological and Medical Systems (BMS 2015), Berlin, Germany, 31/08/2015 - 31/08/2015
Main Research Area: Technical/natural sciences

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BFI (2016): BFI-level 1
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.228 SNIP 0.217 CiteScore 0.27
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.252 SNIP 0.242 CiteScore 0.26
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.249 SNIP 0.22 CiteScore 0.27
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.204 SNIP 0.165 CiteScore 0.17
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.142 SNIP 0.078 CiteScore 0.05
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.121 SNIP 0.054
BFI (2009): BFI-level 1
A Continuous-Discrete Extended Kalman Filter for State and Parameter Estimation in People with Type 1 Diabetes

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Center for Energy Resources Engineering, Slovak University of Technology, Technical University of Denmark, Copenhagen University Hospital
Number of pages: 1
Publication date: 2015
Main Research Area: Technical/natural sciences

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 systems. 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.

General information
State: Published
Organisations: Department of Electrical Engineering, Automation and Control, Department of Informatics and Mathematical Modeling, Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Niemann, H. H. (Intern), Poulsen, N. K. (Intern)
Pages: 883-888
Publication date: 2015
Main Research Area: Technical/natural sciences
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 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.

General information

State: Published
Organisations: Department of Electrical Engineering, Automation and Control, Department of Applied Mathematics and Computer Science, Dynamical Systems, Norwegian University of Science and Technology, VESTAS Wind Systems A/S
Authors: Galeazzi, R. (Intern), Borup, K. T. (Ekstern), Niemann, H. H. (Intern), Poulsen, N. K. (Intern), Caponetti, F. (Ekstern)
Pages: 3058-3065
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Series: American Control Conference
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Main Research Area: Technical/natural sciences
Conference: 2015 American Control Conference, Chicago, IL, United States, 01/07/2015 - 01/07/2015
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Galeazzi_Borup_2015.pdf
DOIs:
10.1109/ACC.2015.7171802
A Homogeneous and Self-Dual Interior-Point Linear Programming Algorithm for Economic Model Predictive Control

We develop an efficient homogeneous and self-dual interior-point method (IPM) for the linear programs arising in economic model predictive control of constrained linear systems with linear objective functions. The algorithm is based on a Riccati iteration procedure, which is adapted to the linear system of equations solved in homogeneous and self-dual IPMs. Fast convergence is further achieved using a warm-start strategy. We implement the algorithm in MATLAB and C. Its performance is tested using a conceptual power management case study. Closed loop simulations show that 1) the proposed algorithm is significantly faster than several state-of-the-art IPMs based on sparse linear algebra, and 2) warm-start reduces the average number of iterations by 35-40%.

General information
State: Published
Authors: Sokoler, L. E. (Intern), Frison, G. (Intern), Skajaa, A. (Intern), Halvgaard, R. F. (Intern), Jørgensen, J. B. (Intern)
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Main Research Area: Technical/natural sciences

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Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): SJR 4.174 SNIP 3.159 CiteScore 6.06
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 3.926 SNIP 2.884 CiteScore 5.08
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 4.196 SNIP 3.347 CiteScore 5.14
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 4.096 SNIP 3.13 CiteScore 5.24
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 4.143 SNIP 3.292 CiteScore 5.11
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 3.749 SNIP 2.961 CiteScore 4.11
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.939 SNIP 2.917
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 3.945 SNIP 3.449
BFI (2008): BFI-level 2
Web of Science (2008): Indexed yes
Scopus rating (2006): SJR 3.67 SNIP 2.917
An artificial pancreas for automated blood glucose control in patients with Type 1 diabetes

Automated glucose control in patients with Type 1 diabetes is much-coveted by patients, relatives and healthcare professionals. It is the expectation that a system for automated control, also know as an artificial pancreas, will improve glucose control, reduce the risk of diabetes complications and markedly improve patient quality of life. An artificial pancreas consists of portable devices for glucose sensing and insulin delivery which are controlled by an algorithm residing on a computer. The technology is still under development and currently no artificial pancreas is commercially available. This review gives an introduction to recent progress, challenges and future prospects within the field of artificial pancreas research.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Copenhagen University Hospital
Authors: Schmidt, S. (Ekstern), Boiroux, D. (Intern), Ranjan, A. (Ekstern), Jørgensen, J. B. (Intern), Madsen, H. (Intern), Nørgaard, K. (Ekstern)
Pages: 211-221
Publication date: 2015
Main Research Area: Technical/natural sciences

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ISSN (Print): 2041-5990
Ratings:
Web of Science (2018): Indexed yes
Scopus rating (2016): SJR 0.637 SNIP 0.544 CiteScore 1.88
Scopus rating (2015): SJR 0.761 SNIP 0.57 CiteScore 2.16
Scopus rating (2014): SJR 0.689 SNIP 0.564 CiteScore 2.02
Scopus rating (2013): SJR 0.606 SNIP 0.477 CiteScore 1.69
Scopus rating (2012): SJR 0.353 SNIP 0.356 CiteScore 0.93
Scopus rating (2011): SJR 0.203 SNIP 0.101 CiteScore 0.64
Original language: English
DOIs:
10.4155/tde.15.12
Source: Findit
Source-ID: 2265611466
Publication: Research - peer-review › Journal article – Annual report year: 2015

A Non-linear Stochastic Model for an Office Building with Air Infiltration

This paper presents a non-linear heat dynamic model for a multi-room office building with air infiltration. Several linear and non-linear models, with and without air infiltration, are investigated and compared. The models are formulated using stochastic differential equations and the model parameters are estimated using a maximum likelihood technique. Based on the maximum likelihood value, the different models are statistically compared to each other using Wilk's likelihood ratio test. The model showing the best performance is finally verified in both the time domain and the frequency domain using
the auto-correlation function and cumulated periodogram. The proposed model which includes air-infiltration shows a significant improvement compared to previously proposed linear models. The model has subsequently been used in applications for provision of power system services, e.g. by providing heat load reduction during peak load hours, control of indoor air temperature and for generating forecasts of power consumption from space heating.

**General information**

State: Published
Organisations: Department of Electrical Engineering, Center for Electric Power and Energy, Energy system operation and management, Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Thavlov, A. (Intern), Madsen, H. (Intern)
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**A robust optimization approach to energy and reserve dispatch in electricity markets**

To a large extent, electricity markets worldwide still rely on deterministic procedures for clearing energy and reserve auctions. However, increasing shares of the production mix consist of renewable sources whose nature is stochastic and non-dispatchable, as their output is uncertain and cannot be controlled by the operators of the production units. Stochastic programming models allow the joint determination of the day-ahead energy and reserve dispatch accounting for the uncertainty in the output from these sources. However, the size of these models gets quickly out of hand as a large number of scenarios are needed to properly represent the uncertainty. In this work, we take an alternative approach and cast the problem as an adaptive robust optimization problem. The resulting day-ahead energy and reserve schedules yield the minimum system cost, accounting for the cost of the redispatch decisions at the balancing (real-time) stage, in the worst-case realization of the stochastic production within a specified uncertainty set. We propose a novel reformulation of the problem that allows considering general polyhedral uncertainty sets. In a case-study, we show that, in comparison to a risk-averse stochastic programming model, the robust optimization approach progressively trades off optimality in expectation with improved performance in terms of risk. These differences, however, gradually taper off as the level of risk-aversion increases for the stochastic programming approach. Computational studies show that the robust optimization model scales well with the size of the power system, which is promising in view of real-world applications of this approach.

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Ohio State University
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**Publication information**

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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.
Bi-hormonal Closed-loop Control of Blood Glucose for People With Type 1 Diabetes - the Diacon Project

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Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Center for Energy Resources Engineering, Copenhagen University Hospital, Slovak University of Technology
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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 uses 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.
Characterising the Actual Thermal Performance of Buildings: Current Results of Common Exercises Performed in the Framework of the IEA EBC Annex 58-Project

Several studies have shown that actual thermal performance of buildings after construction may deviate significantly from that anticipated at design stage. As a result, there is growing interest in full scale testing of components and whole buildings. The IEA EBC Annex 58-project 'Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements' is developing the necessary knowledge and tools to achieve reliable in-situ dynamic testing and data analysis methods that can be used to characterise the actual thermal performance and energy efficiency of building components and whole buildings. The research within this project is driven by case studies. As a first simple case, an experiment on testing and data analysis is performed on a round robin test box. This test box can be seen as a scale model of a building, built by one of the participants, with fabric properties unknown to all other participants. Full scale measurements have been performed on the test box in different countries under real climatic conditions. The obtained dynamic data are distributed to all participants who have to try to characterise the thermal performance of the test box’s fabric based on the provided data.

This paper presents the first results obtained on the round robin experiment. It is shown how different techniques can be used to characterise the thermal performance of the test box, ranging from a simple stationary analysis to advanced dynamic data analysis methods.
Closed loop identification using a modified Hansen scheme: Paper

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.

General information
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Organisations: Department of Electrical Engineering, Automation and Control, Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Mechanical Engineering, Solid Mechanics
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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.

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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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.

General information
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BFi (2011): BFI-level 1
Scopus rating (2011): SJR 0.142 SNIP 0.078 CiteScore 0.05
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BFi (2010): BFI-level 1
Scopus rating (2010): SJR 0.121 SNIP 0.054
BFi (2009): BFI-level 1
Scopus rating (2009): SJR 0.111 SNIP 0.032
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Comparison of two stochastic techniques for reliable urban runoff prediction by modeling systematic errors

In urban rainfall-runoff, commonly applied statistical techniques for uncertainty quantification mostly ignore systematic output errors originating from simplified models and erroneous inputs. Consequently, the resulting predictive uncertainty is often unreliable. Our objective is to present two approaches which use stochastic processes to describe systematic deviations and to discuss their advantages and drawbacks for urban drainage modeling. The two methodologies are an external bias description (EBD) and an internal noise description (IND, also known as stochastic gray-box modeling). They emerge from different fields and have not yet been compared in environmental modeling. To compare the two approaches, we develop a unifying terminology, evaluate them theoretically, and apply them to conceptual rainfall-runoff modeling in the same drainage system. Our results show that both approaches can provide probabilistic predictions of wastewater discharge in a similarly reliable way, both for periods ranging from a few hours up to more than 1 week ahead of time. The EBD produces more accurate predictions on long horizons but relies on computationally heavy MCMC routines for parameter inferences. These properties make it more suitable for off-line applications. The IND can help in diagnosing the causes of output errors and is computationally inexpensive. It produces best results on short forecast horizons that are typical for online applications.

General information
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Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
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ISI indexed (2012): ISI indexed yes
Consumption management in the Nord Pool region: A stability analysis

Integration of fluctuating renewables like wind and solar power is nowadays a hot topic, but this comes at a cost of decreased stability of the power system. The deterioration often translates into so-called spikes and drops in the electricity spot price, very large (even extreme) deviations from the regular spot price, followed by a reversion to roughly the original level a few days later. We use the spikes and drops as strong indications that there is an imbalance in the physical power system in this paper.

Independent Spike Models (ISM) is a popular class of models for the electricity spot price that uses regime switching, typically having three regimes (base regime, spikes and drops). We fit a such model to Nord Pool spot data to characterize the size and intensity of these deviations, and proceed by augmenting the standard second generation, three factor Independent Spike Model by relating the spike and drop intensity to several factors and find strong statistical support for relating the consumption to the spike and drop intensity.

The model is then used to quantitatively evaluate the effects when modifying the consumption in order to mimic how additional renewables are integrated into the power system or conversely the effects when smoothing consumption using strategies that can be implemented in smart grids. We use this tool to obtain a direct measure of how much the spike and drop intensity can be reduced by smoothing the consumption and see that even a small increase in the variability of the consumption translates into decreased stability (more spikes and/or drops) of the power system.
Coupling of weather forecasts and smart grid-control of wastewater inlet to Kolding WWTP (Denmark)
The increasing focus on renewable energy sources has caused many countries to initiate a shift to a more intelligent and flexible electricity system – the Smart Grid. This allows for the optimization of the electricity consumption according to the fluctuation in electricity prices. In this study four strategies for controlling the wastewater flow to Kolding Central wastewater treatment plant (WWTP) based on the Smart Grid concept are investigated. The control strategies use the storage volume in the pipe system upstream the WWTP to detain water during hours with high electricity prices, releasing the water when the price decreases. A lumped conceptual model was constructed based on an existing highly detailed hydrodynamic model of the catchment. The conceptual model was used to assess the performance of the four control strategies, which were evaluated based on savings in operation cost and emitted CO2 equivalents. Weather forecasts were used to empty out the system prior to a rain event, ensuring that the control strategies did not lead to increases in combined sewer overflow. The largest savings obtained were 833 EUR/month and 3909 kg CO2 equivalents/month, which were achieved by only sending wastewater to the treatment plant during the six cheapest hours of the day. The savings
achieved with the other control strategies were however in the ranges 65–300 EUR/month and 196–910 kg CO2 equivalents/month. These evaluations were generally done with limited storage space of just around 20 % of the daily wastewater flow and relatively simplistic control schemes. Larger savings would be anticipated with more complex control schemes utilizing larger storage volumes.

Danish holsteins favor bull offspring: Biased Milk Production as a Function of Fetal Sex, and Calving Difficulty
In a previous study from 2014 it was found that US Holstein cows that gave birth to heifer calves produced more milk than cows having bull calves. We wanted to assess whether this is also true for Danish cattle. Data from 578 Danish Holstein herds were analysed with a mixed effect model and contrary to the findings in the US, we found that cows produced higher volumes of milk if they had a bull calf compared to a heifer calf. We found a significantly higher milk production of 0.28% in the first lactation period for cows giving birth to a bull calf, compared to a heifer calf. This difference was even higher when cows gave birth to another bull calf, so having two bull calves resulted in a difference of 0.52% in milk production compared to any other combination of sex of the offspring. Furthermore, we found that farmer assisted calvings were associated with a higher milk yield. Cows with no farmer assistance or with veterinary assistance during the most recent calving produced less milk. There were also indications that dams would favor a bull fetus by decreasing milk production during the second pregnancy if the calf born in the first parity was a heifer. We hypothesize that size of calves is a confounding factor for milk production. However, calving weight was not available in the present data set to test this hypothesis.
This paper reviews a number of applications of optimization under uncertainty in energy markets resulting from the research project ENSYMORA. A general mathematical formulation applicable to problems of optimization under uncertainty in energy markets is presented. This formulation can be effortlessly adapted to describe different approaches: the deterministic one (usable within a rolling horizon scheme), stochastic programming and robust optimization. The different features of this mathematical formulation are duly interpreted with a view to the energy applications reviewed in this paper: trading for a price-maker wind power producer, management of heat and power systems, operation for retailers in a dynamic-price market. A selection of results shows the viability and appropriateness of the presented stochastic optimization approaches for managing energy systems under uncertainty.

**General information**

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Dynamic multi-stage dispatch of isolated wind–diesel power systems

An optimal dispatch strategy is crucial for an isolated wind–diesel power system to save diesel fuel and maintain the system stability. The uncertainty associated with the stochastic character of the wind is, though, a challenging problem for this optimization. In this paper, a dynamic multi-stage decision-making model is proposed to determine the diesel power output that minimizes the cost of running and maintaining the wind–diesel power system. Optimized operational decisions for each time period are generated dynamically considering the path-dependent nature of the optimal dispatch policy, given the plausible future realizations of the wind power production. A numerical case study is analyzed and it is demonstrated that the proposed stochastic dynamic optimization model significantly outperforms the traditional deterministic dispatch strategies.
This paper proposes a method of describing the load shifting ability of flexible electrical loads in a manner suitable for existing power system dispatch frameworks. The concept of an asymmetric block offer for flexible loads is introduced. This offer structure describes the ability of a flexible load to provide a response to the power system and the subsequent need to recover. The conventional system dispatch algorithm is altered to facilitate the dispatch of demand response units alongside generating units using the proposed offer structure. The value of demand response is assessed through case studies that dispatch flexible supermarket refrigeration loads for the provision of regulating power. The demand resource is described by a set of asymmetric blocks, and a set of four blocks offers is shown to offer cost savings for the procurement of regulating power in excess of 20%. For comparative purposes, the cost savings achievable with a fully observable and controllable demand response resource are evaluated, using a time series model of the refrigeration loads. The fully modeled resource offers greater savings; however the difference is small and potentially insufficient to justify the investment required to fully model and control individual flexible loads.
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.

**Dantzig-Wolfe decomposition**

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.
**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.

**Experimental bifurcation analysis—Continuation for noise-contaminated zero problems**

Noise contaminated zero problems involve functions that cannot be evaluated directly, but only indirectly via observations. In addition, such observations are affected by a non-deterministic observation error (noise). We investigate the application of numerical bifurcation analysis for studying the solution set of such noise contaminated zero problems, which is highly relevant in the context of equation-free analysis (coarse grained analysis) and bifurcation analysis in experiments, and develop specialized algorithms to address challenges that arise due to the presence of noise. As a working example, we demonstrate and test our algorithms on a mechanical nonlinear oscillator experiment using control based continuation, which we used as a main application and test case for development of the Coco compatible Matlab toolbox Continex that implements our algorithms.
Experimental verification of a real-time power curve for down-regulated offshore wind power plants

General information
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Authors: Giebel, G. (Intern), Göçmen Bozkurt, T. (Intern), Sørensen, P. E. (Intern), Réthoré, P. (Intern), Poulsen, N. K. (Intern), Mirzaei, M. (Intern), Skjelmose, M. R. (Ekstern), Kristoffersen, J. R. (Ekstern)
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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.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Center for Energy Resources Engineering, KU Leuven
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Hydrodynamics studies of cyclic voltammetry for electrochemical micro biosensors
We investigate the effect of flow rate on the electrical current response to the applied voltage in a micro electrochemical system. To accomplish this, we considered an ion-transport model that is governed by the Nernst-Planck equation coupled to the Navier-Stokes equations for hydrodynamics. The Butler-Volmer relation provides the boundary conditions, which represent reaction kinetics at the electrode-electrolyte interface. The result shows that convection drastically affects the rate of surface kinetics. At a physically sufficient high flow rates and lower scan rates, the current response is limited by the convection due to fresh ions being brought to the electrode surface and immediately taken away before any surface reaction. However, at high flow and scan rates, the Faradaic current overrides current due to convection. The model also allows predicting the effect of varying electrolyte concentration and scan rates respectively.

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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Micro- and Nanotechnology, Bioanalytics, Nanoprobes, Center for Intelligent Drug Delivery and Sensing Using Microcontainers and Nanomechanics
Impact of forecast errors on expansion planning of power systems with a renewables target

This paper analyzes the impact of production forecast errors on the expansion planning of a power system and investigates the influence of market design to facilitate the integration of renewable generation. For this purpose, we propose a programming modeling framework to determine the generation and transmission expansion plan that minimizes system-wide investment and operating costs, while ensuring a given share of renewable generation in the electricity supply. Unlike existing ones, this framework includes both a day-ahead and a balancing market so as to capture the impact of both production forecasts and the associated prediction errors. Within this framework, we consider two paradigmatic market designs that essentially differ in whether the day-ahead generation schedule and the subsequent balancing re-dispatch are co-optimized or not. The main features and results of the model set-ups are discussed using an illustrative four-node example and a more realistic 24-node case study.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Centre for IT-Intelligent Energy Systems in Cities, University of Copenhagen
Authors: Pineda, S. (Ekstern), Morales González, J. M. (Intern), Boomsma, T. K. (Ekstern)
Pages: 1113-1122
Publication date: 2015
Main Research Area: Technical/natural sciences

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Volume: 248
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Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.83 SJR 2.505 SNIP 2.339
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.334 SNIP 2.412 CiteScore 3.59
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.186 SNIP 2.485 CiteScore 3.21
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.346 SNIP 2.735 CiteScore 3.25
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.418 SNIP 2.588 CiteScore 3.01
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 2.401 SNIP 2.441 CiteScore 3.02
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 2.477 SNIP 2.435
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 2.326 SNIP 2.577
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.739 SNIP 1.984
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.679 SNIP 2.041
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.299 SNIP 2.023
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.194 SNIP 1.913
Scopus rating (2004): SJR 1.24 SNIP 1.882
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.991 SNIP 1.507
Scopus rating (2002): SJR 0.97 SNIP 1.279
Scopus rating (2001): SJR 1.078 SNIP 1.183
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 1.046 SNIP 1.135
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 1.104 SNIP 1.059
Original language: English
OR in energy, Bilevel programming, Expansion planning, Renewable energy sources, Market design
DOIs:
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Source: PublicationPreSubmission
Source-ID: 115264665
Publication: Research - peer-review › Journal article – Annual report year: 2015

Integrated energy systems; aggregation, forecasting, and control

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Wind Energy, Meteorology, Department of Electrical Engineering, Center for Electric Power and Energy, Energy system operation and management, Centre for IT-Intelligent Energy Systems in Cities, Durham University, Fraunhofer Institute for Wind Energy and Energy System Technology
Authors: Madsen, H. (Intern), Parvizi, J. (Intern), Sempreviva, A. M. (Intern), Bindner, H. W. (Intern), Dent, C. (Ekstern), Mackensen, R. (Ekstern)
Pages: 34-40
Publication date: 2015

Host publication information
Title of host publication: DTU International Energy Report 2015: Energy systems integration for the transition to non-fossil energy systems
In this paper, we tackle the problem of a wind power producer participating in a short-term electricity market that allows for the continuous, but potentially illiquid, intraday trading of energy. Considering the realistic case of a wind farm operating in the western Danish price area of Nord Pool, we build a simple but effective algorithm for the wind power producer to fully benefit from the Elbas intraday market. We then investigate the sensitivity of the obtained benefits to the maximum volume of energy the wind power producer is willing to trade in the intraday market, the ultimate aim of the trade (either to decrease energy imbalances or to increase profits) and to the installed capacity of the wind farm. Our numerical results reveal that the wind power producer can substantially increase his revenues by partaking in the intraday market but with diminishing returns to scale—a result that we attribute to the low liquidity of Elbas.
Introduction to Statistics - eNotes
Online textbook used in the introductory statistics courses at DTU. It provides a basic introduction to applied statistics for engineers. The necessary elements from probability theory are introduced (stochastic variable, density and distribution function, mean and variance, etc.) and thereafter the most basic statistical analysis methods are presented: Confidence band, hypothesis testing, simulation, simple and multiple regression, ANOVA and analysis of contingency tables. Examples with the software R are included for all presented theory and methods.
Kage årsag til iltmangel og indlæggelse på hospital

Ambulance bragte en 58-årig forretningsrejsende til akutmodtagelsen med åndenød, svimmelhed og kvalme. Denne og andre cases viser, at man skal have respekt for kuldioxid.

Kommentarer til Modeller for Danske Fjorde og Kystnære Havområder
Bibliographical note
Delrapport som produkt af rekvireret arbejde for Landbrug & Fødevarer. Formålet er at kommentere og diskutere resultaterne præsenteret i den tredelte rapport “Modeller for Danske Fjorde og Kystnære Havområder”, som er udarbejdet af DHI og Aarhus Universitet, DCE. Der er desuden udgivet en opfølgning til denne delrapport: "Kommentarer til Modeller for Danske Fjorde og Kystnære Havområder - opfølgning".
Publication: Commissioned › Report – Annual report year: 2016

Kommentarer til Modeller for Danske Fjorde og Kystnære Havområder - opfølgning

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Møller, J. K. (Intern), Christiansen, L. E. (Intern)
Number of pages: 3
Publication date: 2015

Publication information
Original language: Danish
Main Research Area: Technical/natural sciences
Electronic versions:
LogF_DTU_Compute_part2.pdf

Bibliographical note
Opfølgning på delrapporten "Kommentarer til Modeller for Danske Fjorde og Kystnære Havområder" der er et produkt af rekvireret arbejde for Landbrug & Fødevarer.
Publication: Commissioned › Other contribution – Annual report year: 2016

Limited area forecasting for wind energy scheduling

General information
State: Published
Authors: Rosgaard, M. H. (Intern), Hahmann, A. N. (Intern), Madsen, H. (Intern), Giebel, G. (Intern), Sørensen, P. E. (Intern), Nielsen, H. A. (Ekstern), Nielsen, T. S. (Ekstern)
Number of pages: 1
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Event: Poster session presented at UCD Energy Institute and Electricity Research Centre Annual Symposium, Dublin, Ireland.
Main Research Area: Technical/natural sciences
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Source-ID: 118350095
Publication: Research › Poster – Annual report year: 2015

Long memory of financial time series and hidden Markov models with time-varying parameters
Hidden Markov models are often used to capture stylized facts of daily returns and to infer the hidden state of financial markets. Previous studies have found that the estimated models change over time, but the implications of the time-varying behavior for the ability to reproduce the stylized facts have not been thoroughly examined. This paper presents an adaptive estimation approach that allows for the parameters of the estimated models to be time-varying. It is shown that a two-state Gaussian hidden Markov model with time-varying parameters is able to reproduce the long memory of squared daily returns that was previously believed to be the most difficult fact to reproduce with a hidden Markov model. Capturing the time-varying behavior of the parameters also leads to improved one-step predictions.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Nystrup, P. (Intern), Madsen, H. (Intern), Lindstrøm, E. (Ekstern)
Mean effective sensitivity for Mycobacterium avium subsp.paratuberculosis infection in cattle herds

Background: Mycobacterium avium subsp. paratuberculosis (MAP) infections in cattle are generally challenging to detect and cost-effective test strategies are consequently difficult to identify. MAP-specific antibody ELISAs for milk and serum are relatively inexpensive, but their utility is influenced by a number of factors such as herd size, herd composition and diagnostic sensitivity. The sensitivity of the test increases with the age of the tested animal, and therefore the general, or "mean effective sensitivity" (defined as the mean of the sensitivities for all animals within a population, MES), for detecting MAP within a herd is dependent upon the age distribution of the herd. For this study we used a dataset of cattle from 4,259 dairy herds and 4,078 non-dairy herds. The aim was to investigate the MES for groups of cattle considered to be reasonable entities for MAP surveillance and control, in order to assist the decision-makers in planning and optimizing these programs economically. We compared six different groups of cattle (three dairy and three non-dairy) in Denmark by calculating the MES for each herd in each group.

Results: The distribution of MES showed a large variation within and between groups, and in some groups we found a bimodal distribution of MES. Dairy herds generally showed higher MES than non-dairy herds. Dairy herds in a control programme for paratuberculosis showed a MES similar to all other dairy herds from which animals >2.0 years were tested (both groups had a median MES = 0.60). For the non-dairy groups, the sensitivity became much higher when animals <2.0 years and herds with less than 25 cattle were excluded, resulting in a median MES of 0.65.

Conclusion: The results showed that MES could indicate the effectivity of testing different cattle groups for MAP, given that the data used are unbiased.

General information
State: Published
Organisations: National Veterinary Institute, Section for Epidemiology, Department of Applied Mathematics and Computer Science, Dynamical Systems, University of Copenhagen
Authors: Kirkeby, C. (Intern), Græsbøll, K. (Intern), Hisham Beshara Halasa, T. (Intern), Toft, N. (Intern), Nielsen, S. S. (Ekstern)
Number of pages: 6
Publication date: 2015
Main Research Area: Technical/natural sciences

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Journal: BMC Veterinary Research
Volume: 11
Issue number: 1
Article number: 190
ISSN (Print): 1746-6148
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BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.83 SJR 0.847 SNIP 0.983
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.925 SNIP 0.97 CiteScore 1.86
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.885 SNIP 0.987 CiteScore 1.81
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.829 SNIP 0.833 CiteScore 1.85
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
In this report models for extreme negative wind power forecast errors are presented. The models can be applied to estimate levels below which the wind power rarely drops. Such levels could be called “certain-levels” or “guaranteed levels” of wind power, well knowing that full guarantee never can be given. The estimated levels are obtained by modelling the error from already existing wind power forecasting software, this is accomplished by modelling the residuals with statistical extreme value techniques.

The forecasts can be used in the operation of power systems with significant amounts of wind power for example in the planning of ancillary power services, where the level of available wind power with a high degree of certainty is important to know.

The presented extreme value models are applied to negative forecast residuals from state-of-the-art wind power forecast software. This enables the estimation of return levels below which the extreme wind power forecast error events occur only at a specified rate, e.g. once a month or once every year. The techniques allows extrapolation beyond the available data period. In the study data from 1.5 years is used. It consists of hourly wind power production in the two regions of Denmark (DK1 and DK2) and corresponding wind power forecasts. The wind power forecasts are generated using the software WPPT and are based on the outcome of three numerical weather prediction models. They cover horizons from 1 to 42 hours ahead in time and are updated each hour.

In the report a range of extreme value models are suggested. They are of increasing complexity and a model selection is carried using statistical measures and test. A normal procedure when building forecasting models is to divide the data into a learning and a test set to cross-validate the results in order to avoid over-fitting the models. This is hardly ever possible for extreme value analysis, instead the model selection and evaluation sole rely on statistical techniques such as correlation measures, likelihood ratio-tests and information about uncertainty, for example in the form of confidence bands on parameter estimates and predictions.

The foundation to statistical extreme value theory was set by Fisher and Tippett in 1928 and later developed by Gumbel (1958). Since then it has been used for modelling extremes in a wide range of applications. Typical applications are for estimation of extreme weather induced phenomena, for example extreme water levels in a river, wind levels or at sea for
design of dykes (de Haan and de Ronde, 1998). In insurance and finance the extreme value modelling is widespread
(Embrechts et al., 1997). Extreme value statistics for energy and power applications is also widely used, for example for
planning in wind power operation (Hovat et al., 2013) and peak wind prediction (Cook, 1982) and (Friederichs and
Thorarinssdottrí, 2012). Several books provide comprehensive introductions to extreme value theory, for example Coles
(2001) and Beirlant et al. (2006). A really good overview of available extreme value analysis software is given by
(Stephenson and Gilleland, 2005). In the present study the R R Core Team (2013) package extRemes Gilleland and Katz
(2011) is used.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science , Dynamical Systems, Department of Electrical
Engineering, Center for Electric Power and Energy, Energy Analytics and Markets, ENFOR A/S
Authors: Bacher, P. (Intern), Madsen, H. (Intern), Pinson, P. (Intern), Mortensen, S. B. (Ekstern), Nielsen, H. A. (Ekstern)
Number of pages: 73
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Number: 01
ISSN: 1601-2321
Main Research Area: Technical/natural sciences
Electronic versions:
tr15_01_Bacher_P.pdf
Publication: Research › Report – Annual report year: 2015

Numerical Modeling of Microelectrochemical Systems
The PhD dissertation is concerned with mathematical modeling and simulation of electrochemical systems. The first three
chapters of the thesis consist of the introductory part, the model development chapter and the chapter on the summary of
the main results. The remaining three chapters report three independent papers and manuscripts.

As a preliminary to the study, we describe a general model for electrochemical systems and study their underlying
mechanisms through electroanalytical techniques. We then extend the model to a more realistic model for
microelectrochemical systems which incorporates the finite size of ionic species in the transport equation. The model
presents a more appropriate boundary conditions which describe the modified Butler-Volmer reaction kinetics and account
for the surface capacitance of the thin electric double layer. We also have found analytical solution for the reactants in the
bulk electrolyte that are traveling waves.

The first paper presents the mathematical model which describes an electrochemical system and simulates an
electroanalytical technique called cyclic voltammetry. The model is governed by a system of advection–diffusion equations
with a nonlinear reaction term at the boundary. We investigate the effect of flow rates, scan rates, and concentration on
the cyclic voltammetry. We establish that high flow rates lead to the reduced hysteresis in the cyclic voltammetry curves
and increasing scan rates lead to more pronounced current peaks. The final part of the paper shows that the response
current in a cyclic voltammetry increases proportionally to the electrolyte concentration.

In the second paper we present an experiment of an electrochemical system in a microfluidic system and compare the
result to the numerical solutions. We investigate how the position of the electrodes in the system affects the recorded
cyclic voltammetry. The result shows that convection influences the charge transfer dynamics on the electrode surface
and hence the cyclic voltammetry recorded. In terms of relative high flow to scan rates, the current response is dominated
by the convection due to the fresh supply of reactants towards the electrode surface and quick removal of the products.
We also establish that at high scan rates and modest flow rates, peak currents are recorded. Finally, the results show that
the position of the electrodes is critical when performing cyclic voltammetry under the flow condition. The numerical results
show promising agreement with experimental findings which could be critical in designing highly sensitive electrochemical
systems.

The last paper explores the numerical solution which describes the non-linear transient responses to a large applied
potential at the electrode in a microelectrochemical system. In our analysis, we account for the finite size properties of ions
in the mass and the charge transport of ionic species in an electrochemical system. This term characterizes the saturation
of the ionic species close to the electrode surface. We then analyse the responses of the system on the charging of the
electric double layer. We consider an arbitrary electrolyte solution that is sandwiched between electrodes and allow for
electrochemical reactions at the electrode/electrolyte interface. One of the electrodes is biased with a potential which
triggers the reaction and the dynamics of the system. We establish that there is a quick build up of boundary layers in the
double layer, but the finite size constraint on the ionic species prevents overcrowding of the ionic species. The result also
shows that reactants which undergo charge transfer at the electrode/electrolyte interface crowded the electric double layer and the dynamics of the electric double layer is controlled by the charge transfer.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Scientific Computing
Authors: Adesokan, B. J. (Intern), Evgrafov, A. (Intern), Sørensen, M. P. (Intern)
Number of pages: 116
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Main Research Area: Technical/natural sciences
Electronic versions: phd362_Adesokan_BJ.pdf
Publication: Research Ph.D. thesis – Annual report year: 2015

On the Inclusion of Energy-Shifting Demand Response in Production Cost Models: Methodology and a Case Study

In the context of future power system requirements for additional flexibility, demand response (DR) is an attractive potential resource. Its proponents widely laud its prospective benefits, which include enabling higher penetrations of variable renewable generation at lower cost than alternative storage technologies, and improving economic efficiency. In practice, DR from the commercial and residential sectors is largely an emerging, not a mature, resource, and its actual costs and benefits need to be studied to determine promising combinations of physical DR resource, enabling controls and communications, power system characteristics, regulatory environments, market structures, and business models. The work described in this report focuses on the enablement of such analysis from the production cost modeling perspective. In particular, we contribute a bottom-up methodology for modeling load-shifting DR in production cost models. The resulting model is sufficiently detailed to reflect the physical characteristics and constraints of the underlying flexible load, and includes the possibility of capturing diurnal and seasonal variations in the resource. Nonetheless, the model is of low complexity and thus suitable for inclusion in conventional unit commitment and market clearing algorithms. The ability to simulate DR as an operational resource on a power system over a year facilitates an assessment of its time-varying value to the power system.

The modeling methodology is demonstrated through a case study of aggregated supermarket refrigeration systems providing balancing energy reserves in real-time markets at different levels of variable generation (VG). This DR resource is implemented in a test power system that represents a subset of the U.S Western Interconnection centered on Colorado. The value of DR from the population of supermarkets in Colorado is found to be $32.85 per kilowatt-year (kW-yr) presuming no other DR resources. The value decreases significantly (to $6.95/kW-year in the most extreme case) when we increase the capacity of the DR resource to naively represent the incorporation of DR from other flexible loads (in actuality, other DR resources will have different characteristics, such that the decrease in value will not be as steep). Refrigeration DR is found to offer greater value to the power system during the winter months than the summer months due to operational constraints that limit the flexibility of the resource during the summer. The value of DR is found to increase as the penetration of VG increases, reaching $46.05/kW-year for our baseline DR penetration and a variable generation (VG) penetration of 55%. We do see a plateau in the value of DR going from 45% to 55% VG. This is attributable to the inability of DR to provide energy storage on horizons longer than 24 hours.

Overall, this work is a study in methodology. The case study is included primarily to show that the model is working properly and that this line of research is worthwhile. The reported numbers do not represent a true value of DR, but they do suggest orders of magnitude for a particular DR resource providing a particular grid service in a particular power system; they also confirm expected correlation directions between value and DR penetration (decreasing) and between value and VG penetration (increasing). Future work includes extending this method and developing new methods to be able to model physically realistic DR resources at scale. Some important aspects not studied here include capturing all possible value streams for a single resource (capacity, energy, and ancillary service values), simultaneously evaluating DR from multiple resources, and economically competing DR resources based on their costs of enablement and the trade-offs between end-user disutility and participation payments.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, National Renewable Energy Laboratory
Authors: O’Connell, N. (Intern), Hale, E. (Ekstern), Doebber, I. (Ekstern), Jorgenson, J. (Ekstern)
Operational Strategies for a Portfolio of Wind Farms and CHP Plants in a Two-Price Balancing Market

In this paper we explore the portfolio effect of a system consisting of a Combined Heat and Power (CHP) plant and a wind farm. The goal is to increase the overall profit of the portfolio by reducing imbalances, and consequently their implicit penalty in a two-price balancing market for electricity. We investigate two different operational strategies, which differ in whether the CHP plant and the wind farm are operated jointly or independently, and we evaluate their economic performance on a real case study based on a CHP-wind system located in the western part of Denmark. We present a comprehensive mathematical model for describing the different heat and power production units of the CHP plant, and suggest different ways of determining its operation in a setup with two trading floors: a day-ahead market and a balancing market. We build a simulation framework that runs in a rolling-horizon fashion, so that forecasts for heat demand, wind power production and market prices are updated at each iteration. We conclude that the portfolio strategy is the most profitable due to the two-price structure of the balancing market. This encourages producers to handle their imbalances outside the market.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Centre for IT-Intelligent Energy Systems in Cities, DONG Energy A/S
Authors: Hellmers, A. (Ekstern), Zugno, M. (Intern), Skajaa, A. (Ekstern), Morales González, J. M. (Intern)
Number of pages: 10
Publication date: 2015
Main Research Area: Technical/natural sciences

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Volume: PP
Issue number: 99
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Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 8.17 SJR 3.757 SNIP 3.624
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 3.602 SNIP 3.486 CiteScore 6.6
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.831 SNIP 3.577 CiteScore 5.31
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.939 SNIP 4.35 CiteScore 6.33
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.

General information

State: Published
Organisations: Department of Electrical Engineering, Automation and Control, Department of Applied Mathematics and Computer Science, Dynamical Systems, DNV-GL Oil & Gas, Wallenius Marine
Authors: Galeazzi, R. (Intern), Blanke, M. (Intern), Falkenberg, T. (Intern), Poulsen, N. K. (Intern), Violaris, N. (Ekstern), Storhaug, G. (Ekstern), Huss, M. (Ekstern)
Pharmacodynamic modelling of in vitro activity of tetracycline against a representative, naturally occurring population of porcine Escherichia coli

The complex relationship between drug concentrations and bacterial growth rates require not only the minimum inhibitory concentration but also other parameters to capture the dynamic nature of the relationship. To analyse this relationship between tetracycline concentration and growth of Escherichia coli representative of those found in the Danish pig population, we compared the growth of 50 randomly selected strains. The observed net growth rates were used to describe the in vitro pharmacodynamic relationship between drug concentration and net growth rate based on E max model with three parameters: maximum net growth rate (α max ); concentration for a half-maximal response (E max ); and the Hill coefficient (γ). The net growth rate in the absence of antibiotic did not differ between susceptible and resistant isolates (P = 0.97). The net growth rate decreased with increasing tetracycline concentrations, and this decline was greater in susceptible strains than resistant strains. The lag phase, defined as the time needed for the strain to reach an OD600 value of 0.01, increased exponentially with increasing tetracycline concentration. The pharmacodynamic parameters confirmed that the in vitro model parameters described the inhibition effect of tetracycline on E. coli when strains were exposed to a wide range of tetracycline concentrations. These parameters, along with in vivo pharmacokinetic data, may be useful in mathematical models to predict in vivo competitive growth of many different strains and for development of optimal dosing regimens for preventing selection of resistance.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, National Veterinary Institute, Section for Epidemiology, Department of Microbiology, University of Copenhagen, University of Glasgow
Authors: Ahmad, A. (Ekstern), Zachariasen, C. (Ekstern), Christiansen, L. E. (Intern), Græsbøll, K. (Intern), Toft, N. (Intern), Matthews, L. (Ekstern), Damborg, P. (Ekstern), Agerse, Y. (Intern), Olsen, J. E. (Ekstern), Nielsen, S. S. (Ekstern)
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Publication date: 2015
Main Research Area: Technical/natural sciences

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Issue number: 1
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Web of Science (2018): Indexed yes
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Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.01 SJR 0.484 SNIP 0.775
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.409 SNIP 1.445 CiteScore 0.98
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.644 SNIP 1.113 CiteScore 1.54
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.494 SNIP 1.001 CiteScore 1.41
ISI indexed (2013): ISI indexed no
Web of Science (2013): Indexed yes
Pharmacokinetic-Pharmacodynamic Model To Evaluate Intramuscular Tetracycline Treatment Protocols To Prevent Antimicrobial Resistance in Pigs

High instances of antimicrobial resistance are linked to both routine and excessive antimicrobial use, but excessive or inappropriate use represents an unnecessary risk. The competitive growth advantages of resistant bacteria may be amplified by the strain dynamics; in particular, the extent to which resistant strains outcompete susceptible strains under antimicrobial pressure may depend not only on the antimicrobial treatment strategies but also on the epidemiological parameters, such as the composition of the bacterial strains in a pig. This study evaluated how variation in the dosing protocol for intramuscular administration of tetracycline and the composition of bacterial strains in a pig affect the level of resistance in the intestine of a pig. Predictions were generated by a mathematical model of competitive growth of \textit{Escherichia coli} strains in pigs under specified plasma concentration profiles of tetracycline. All dosing regimens result in a clear growth advantage for resistant strains. Short treatment duration was found to be preferable, since it allowed less time for resistant strains to outcompete the susceptible ones. Dosing frequency appeared to be ineffective at reducing the resistance levels. The number of competing strains had no apparent effect on the resistance level during treatment, but possession of fewer strains reduced the time to reach equilibrium after the end of treatment. To sum up, epidemiological parameters may have more profound influence on growth dynamics than dosing regimens and should be considered when designing improved treatment protocols.
Pharmacokinetics Modeling of Glucagon and a Novel Glucagon Analogue after Subcutaneous Administration in Dogs

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Zealand Pharma A/S
Authors: Wendt, S. L. (Intern), Valeur, A. (Ekstern), Madsen, H. (Intern), Jørgensen, J. B. (Intern), Boye Knudsen, C. (Ekstern)
Number of pages: 1
Publication date: 2015
Event: Poster session presented at The 8th International Conference on Advanced Technologies and Treatments for Diabetes (ATTD 2015), Paris, France.
Main Research Area: Technical/natural sciences
Electronic versions:
Eposter_final2_comp.pdf
Source: PublicationPreSubmission
Source-ID: 106095949
Publication: Research › Poster – Annual report year: 2015

Real-time available power estimation for offshore wind power plants

General information
State: Published
Authors: Göçmen Bozkurt, T. (Intern), Giebel, G. (Intern), Sørensen, P. E. (Intern), Réthoré, P. (Intern), Mirzaei, M. (Intern), Poulsen, N. K. (Intern), Skjelmose, M. R. (Ekstern), Kristoffersen, J. R. (Ekstern)
Number of pages: 1
Publication date: 2015
Event: Poster session presented at EWEA Offshore 2015 Conference, Copenhagen, Denmark.
Main Research Area: Technical/natural sciences
Electronic versions:
Poster
Publication: Research › Poster – Annual report year: 2015

Regime-Based Versus Static Asset Allocation: Letting the Data Speak
Regime shifts present a big challenge to traditional strategic asset allocation. This article investigates whether regime-based asset allocation can effectively respond to changes in financial regimes at the portfolio level, in an effort to provide better long-term results than more static approaches can offer. The authors center their regime-based approach around a regime-switching model with time-varying parameters that can match financial markets' tendency to change
behavior abruptly and the fact that the new behavior often persists for several periods after a change. In an asset universe consisting of a global stock index and a global government bond index, they show that, even without any level of forecasting skill, holding a static portfolio may not be optimal.

**Sampling and Pooling Methods for Capturing Herd Level Antibiotic Resistance in Swine Feces using qPCR and CFU Approaches**

The aim of this article was to define the sampling level and method combination that captures antibiotic resistance at pig herd level utilizing qPCR antibiotic resistance gene quantification and culture-based quantification of antibiotic resistant coliform indicator bacteria. Fourteen qPCR assays for commonly detected antibiotic resistance genes were developed,
and used to quantify antibiotic resistance genes in total DNA from swine fecal samples that were obtained using different sampling and pooling methods. In parallel, the number of antibiotic resistant coliform indicator bacteria was determined in the same swine fecal samples. The results showed that the qPCR assays were capable of detecting differences in antibiotic resistance levels in individual animals that the coliform bacteria colony forming units (CFU) could not. Also, the qPCR assays more accurately quantified antibiotic resistance genes when comparing individual sampling and pooling methods. qPCR on pooled samples was found to be a good representative for the general resistance level in a pig herd compared to the coliform CFU counts. It had significantly reduced relative standard deviations compared to coliform CFU counts in the same samples, and therefore differences in antibiotic resistance levels between samples were more readily detected. To our knowledge, this is the first study to describe sampling and pooling methods for qPCR quantification of antibiotic resistance genes in total DNA extracted from swine feces.

**General information**

State: Published
Organisations: National Veterinary Institute, Section for Bacteriology, Pathology and Parasitology, Department of Applied Mathematics and Computer Science, Dynamical Systems, University of Copenhagen
Authors: Schmidt, G. V. (Intern), Mellerup, A. (Intern), Christiansen, L. E. (Intern), Ståhl, M. (Intern), Olsen, J. E. (Ekstern), Angen, Ø. (Intern)
Publication date: 2015
Main Research Area: Technical/natural sciences

**Publication information**

Journal: PLoS One
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Issue number: 6
Article number: e0131672
ISSN (Print): 1932-6203
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- BFI (2018): BFI-level 1
- Web of Science (2018): Indexed yes
- BFI (2017): BFI-level 1
- Web of Science (2017): Indexed yes
- BFI (2016): BFI-level 1
- Scopus rating (2016): CiteScore 3.11 SJR 1.201 SNIP 1.092
- Web of Science (2016): Indexed yes
- BFI (2015): BFI-level 1
- Scopus rating (2015): SJR 1.414 SNIP 1.131 CiteScore 3.32
- Web of Science (2015): Indexed yes
- BFI (2014): BFI-level 1
- Scopus rating (2014): SJR 1.545 SNIP 1.141 CiteScore 3.54
- Web of Science (2014): Indexed yes
- BFI (2013): BFI-level 1
- Scopus rating (2013): SJR 1.74 SNIP 1.147 CiteScore 3.94
- ISI indexed (2013): ISI indexed yes
- Web of Science (2013): Indexed yes
- BFI (2012): BFI-level 1
- Scopus rating (2012): SJR 1.945 SNIP 1.142 CiteScore 4.15
- ISI indexed (2012): ISI indexed yes
- Web of Science (2012): Indexed yes
- BFI (2011): BFI-level 1
- Scopus rating (2011): SJR 2.369 SNIP 1.23 CiteScore 4.58
- ISI indexed (2011): ISI indexed no
- Web of Science (2011): Indexed yes
- BFI (2010): BFI-level 1
- Scopus rating (2010): SJR 2.631 SNIP 1.161
- Web of Science (2010): Indexed yes
- BFI (2009): BFI-level 1
- Scopus rating (2009): SJR 2.473 SNIP 0.985
- Web of Science (2009): Indexed yes
Simulating cyclic voltammetry under advection for electrochemical cantilevers

We present a mathematical model describing an electrochemical system involving electrode–electrolyte interaction. The model is governed by a system of advection–diffusion equations with a nonlinear reaction term at the boundary. Our calculations based on such model demonstrate the dynamics of ionic currents in the electrolyte. The model allows us to predict the effect of varying flow rates, scan rates, and electrolyte concentration of the electrochemical system.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Center for Intelligent Drug Delivery and Sensing Using Microcontainers and Nanomechanics
Authors: Adesokan, B. J. (Intern), Evgrafov, A. (Intern), Sørensen, M. P. (Intern)
Pages: 3384-3391
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: Mathematical Methods in the Applied Sciences
Volume: 38
Issue number: 16
ISSN (Print): 0170-4214
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.669 SNIP 0.748 CiteScore 0.92
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.755 SNIP 0.837 CiteScore 0.92
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.73 SNIP 0.896 CiteScore 0.85
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.871 SNIP 0.914 CiteScore 0.95
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.876 SNIP 0.851 CiteScore 0.82
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.88 SNIP 0.874 CiteScore 0.85
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.83 SNIP 1
BFI (2009): BFI-level 1
Simulating Spread of Antimicrobial Resistant Bacteria In the Pig Pen: try our online tool

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, National Veterinary Institute, Section for Epidemiology, Dynamical Systems, University of Copenhagen
Authors: Græsbøll, K. (Intern), Nielsen, S. S. (Ekstern), Toft, N. (Intern), Christiansen, L. E. (Intern)
Number of pages: 1
Publication date: 2015
Event: Poster session presented at Annual Conference of The Society for Veterinary Epidemiology and Preventive Medicine, Ghent, Belgium.
Main Research Area: Technical/natural sciences
Electronic versions:
SVEPM4.pdf
Source: PublicationPreSubmission
Source-ID: 110923815
Publication: Research - peer-review › Poster – Annual report year: 2015

Simulating Spread of Antimicrobial Resistant Bacteria In the Pig Pen: try our online tool

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, National Veterinary Institute, Section for Epidemiology, Dynamical Systems, University of Copenhagen
Authors: Græsbøll, K. (Intern), Nielsen, S. S. (Ekstern), Toft, N. (Intern), Christiansen, L. E. (Intern)
Number of pages: 1
Publication date: 2015
Event: Poster session presented at 14th Conference of the International Society for Veterinary Epidemiology and Economics, Mérida, Yucatan, Mexico.
Main Research Area: Technical/natural sciences
Electronic versions:
kagr_ISVEE14.pdf
Publication: Research - peer-review › Poster – Annual report year: 2015

Space-time trajectories of wind power generation: Parameterized precision matrices under a Gaussian copula approach

Emphasis is placed on generating space-time trajectories of wind power generation, consisting of paths sampled from high-dimensional joint predictive densities, describing wind power generation at a number of contiguous locations and successive lead times. A modelling approach taking advantage of the sparsity of precision matrices is introduced for the description of the underlying space-time dependence structure. The proposed parametrization of the dependence structure accounts for important process characteristics such as lead-time-dependent conditional precisions and direction-dependent cross-correlations. Estimation is performed in a maximum likelihood framework. Based on a test case
application in Denmark, with spatial dependencies over 15 areas and temporal ones for 43 hourly lead times (hence, for a dimension of $n = 645$), it is shown that accounting for space-time effects is crucial for generating skilful trajectories.

**General information**

State: Published
Organisations: Department of Electrical Engineering, Department of Applied Mathematics and Computer Science, Dynamical Systems, Centre for IT-Intelligent Energy Systems in Cities, Siemens Wind Power A/S
Authors: Tastu, J. (Ekstern), Pinson, P. (Intern), Madsen, H. (Intern)
Pages: 267-296
Publication date: 2015

**Host publication information**

Title of host publication: Modeling and Stochastic Learning for Forecasting in High Dimensions
Publisher: Springer
Editors: Antoniadis, A., Poggi, J., Brossat, X.
ISBN (Print): 978-3-319-18731-0

**Statistics for Finance**

Statistics for Finance develops students' professional skills in statistics with applications in finance. Developed from the authors' courses at the Technical University of Denmark and Lund University, the text bridges the gap between classical, rigorous treatments of financial mathematics that rarely connect concepts to data and books on econometrics and time series analysis that do not cover specific problems related to option valuation.

The book discusses applications of financial derivatives pertaining to risk assessment and elimination. The authors cover various statistical and mathematical techniques, including linear and nonlinear time series analysis, stochastic calculus models, stochastic differential equations, Ito's formula, the Black–Scholes model, the generalized method-of-moments, and the Kalman filter. They explain how these tools are used to price financial derivatives, identify interest rate models, value bonds, estimate parameters, and much more.

This textbook will help students understand and manage empirical research in financial engineering. It includes examples of how the statistical tools can be used to improve value-at-risk calculations and other issues. In addition, end-of-chapter exercises develop students’ financial reasoning skills.

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Netcompany IT and business consulting A/S, Lund University
Authors: Lindström, E. (Ekstern), Madsen, H. (Intern), Nielsen, J. N. (Intern)
Number of pages: 359
Publication date: 2015

**Publication information**

Publisher: C R C Press LLC
ISBN (Print): 978-1-4822-2899-1
ISBN (Electronic): 978-1-4822-2902-8
Original language: English

Series: Chapman
Main Research Area: Technical/natural sciences
Publication: Research - peer-review › Book – Annual report year: 2015
Stochastic Greybox Modeling of an Alternating Activated Sludge Process

Summary of key findings

We found a greybox model for state estimation and control of the BioDenitro process based on a reduced ASM1. We then applied Maximum Likelihood Estimation on measurements from a real full-scale waste water treatment plant to estimate the model parameters. The estimation method also incorporates the Extended Kalman Filter that provides estimates of any unmeasured states, e.g. the NH4 and NO3 concentrations in both aeration tanks, and more importantly, the NH4 inlet concentration. This will improve control performance without the need for extra sensors and improve forecasts of the load.

General information

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Krüger A/S
Authors: Halvgaard, R. F. (Intern), Munk-Nielsen, T. (Ekstern), Tychsen, P. (Ekstern), Grum, M. (Ekstern), Madsen, H. (Intern)
Number of pages: 3
Publication date: 2015
Event: Abstract from 9th IWA Symposium on Systems Analysis and Integrated Assessment (Watermatex 2015), Gold Coast, Queensland, Australia.
Main Research Area: Technical/natural sciences
WWTP, Greybox, System Identification

Bibliographical note
Extended abstract to be presented as poster at Watermatex
Source: PublicationPreSubmission
Source-ID: 110822871
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2015

Stochastic modelling of Listeria monocytogenes single cell growth in cottage cheese with mesophilic lactic acid bacteria from aroma producing cultures

A stochastic model was developed for simultaneous growth of low numbers of Listeria monocytogenes and populations of lactic acid bacteria from the aroma producing cultures applied in cottage cheese. During more than two years, different batches of cottage cheese with aroma culture were analysed for pH, lactic acid concentration and initial concentration of lactic acid bacteria. These data and bootstrap sampling were used to represent product variability in the stochastic model. Lag time data were estimated from observed growth data (lactic acid bacteria) and from literature on L. monocytogenes single cells. These lag time data were expressed as relative lag times and included in growth models. A stochastic model was developed from an existing deterministic growth model including the effect of five environmental factors and interbacterial interaction [Østergaard, N.B, Eklöw, A and Dalgaard, P. 2014. Modelling the effect of lactic acid bacteria from starter- and aroma culture on growth of Listeria monocytogenes in cottage cheese. International Journal of Food Microbiology. 188, 15-25]. Growth of L. monocytogenes single cells, using lag time distributions corresponding to three different stress levels, was simulated. The simulated growth was subsequently compared to growth of low concentrations (0.4-1.0CFU/g) of L. monocytogenes in cottage cheese, exposed to similar stresses, and in general a good agreement was observed. In addition, growth simulations were performed using population relative lag time distributions for L. monocytogenes as reported in literature. Comparably good predictions were obtained as for the simulations performed using lag time data for individual cells of L. monocytogenes. Therefore, when lag time data for individual cells are not available, it was suggested that relative lag time distributions for L. monocytogenes can be used as a qualified default assumption when simulating growth of low concentrations of L. monocytogenes.

General information

State: Published
Organisations: National Food Institute, Division of Industrial Food Research, Department of Applied Mathematics and Computer Science, Dynamical Systems, Research Group for Microbial Food Safety and Quality
Authors: Østergaard, N. B. (Intern), Christiansen, L. E. (Intern), Dalgaard, P. (Intern)
Number of pages: 11
Pages: 55-65
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: International Journal of Food Microbiology
Volume: 204
ISSN (Print): 0168-1605
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.97 SJR 1.462 SNIP 1.554
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.628 SNIP 1.694 CiteScore 4.02
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.501 SNIP 1.711 CiteScore 3.62
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.602 SNIP 1.86 CiteScore 3.8
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.62 SNIP 1.709 CiteScore 3.7
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.595 SNIP 1.717 CiteScore 3.63
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.593 SNIP 1.665
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.458 SNIP 1.52
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.486 SNIP 1.511
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.33 SNIP 1.69
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.52 SNIP 1.794
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.494 SNIP 1.827
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.479 SNIP 1.636
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 1.229 SNIP 1.63
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 1.109 SNIP 1.288
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 1.036 SNIP 1.506
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 1.02 SNIP 1.292
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 1.06 SNIP 1.209
Original language: English
Variability, Bacterial interaction, Low contamination levels, Fresh fermented dairy products, Relative lag time
DOIs:
10.1016/j.ijfoodmicro.2015.03.022
Source: FindIt
Source-ID: 274887985
Publication: Research - peer-review › Journal article – Annual report year: 2015
Stochastic Unit Commitment via Progressive Hedging - Extensive Analysis of Solution Methods

Owing to the massive deployment of renewable power production units over the last couple of decades, the use of stochastic optimization methods to solve the unit commitment problem has gained increasing attention. Solving stochastic unit commitment problems in large-scale power systems requires high computational power, as stochastic models are dramatically more complex than their deterministic counterparts. This paper provides new insight into the potential of Progressive Hedging to decrease the solution time of the stochastic unit commitment problem with a relatively small trade-off in terms of the suboptimality of the solution. Computational studies show that the run-time is at most half of what is needed to solve the original extensive formulation of the problem, when more than ten wind power scenarios are utilized. These studies demonstrate great potential for solving real-world stochastic unit commitment problems using the Progressive Hedging algorithm.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Electric Power and Energy, Energy Analytics and Markets, Centre for IT-Intelligent Energy Systems in Cities, Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Ordoudis, C. (Intern), Pinson, P. (Intern), Zugno, M. (Intern), Morales González, J. M. (Intern)
Number of pages: 6
Publication date: 2015

Host publication information
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Publisher: IEEE
ISBN (Print): 9781479976935
Main Research Area: Technical/natural sciences
Electricity market operations, Progressive hedging, Stochastic unit commitment, Wind power
DOIs: 10.1109/PTC.2015.7232629
Source: PublicationPreSubmission
Source-ID: 108206682
Publication: Research - peer-review › Article in proceedings – Annual report year: 2015

Stylised facts of financial time series and hidden Markov models in continuous time

Hidden Markov models are often applied in quantitative finance to capture the stylised facts of financial returns. They are usually discrete-time models and the number of states rarely exceeds two because of the quadratic increase in the number of parameters with the number of states. This paper presents an extension to continuous time where it is possible to increase the number of states with a linear rather than quadratic growth in the number of parameters. The possibility of increasing the number of states leads to a better fit to both the distributional and temporal properties of daily returns.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Lund University
Authors: Nystrup, P. (Intern), Madsen, H. (Intern), Lindström, E. (Ekstern)
Pages: 1531-1541
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: Quantitative Finance
Volume: 15
Issue number: 9
ISSN (Print): 1469-7688
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 1 SJR 0.608 SNIP 0.925
Web of Science (2016): Indexed yes
Temporal knowledge discovery in big BAS data for building energy management

With the advances of information technologies, today's building automation systems (BASs) are capable of managing building operational performance in an efficient and convenient way. Meanwhile, the amount of real-time monitoring and control data in BASs grows continually in the building lifecycle, which stimulates an intense demand for powerful big data analysis tools in BASs. Existing big data analytics adopted in the building automation industry focus on mining cross-sectional relationships, whereas the temporal relationships, i.e., the relationships over time, are usually overlooked. However, building operations are typically dynamic and BAS data are essentially multivariate time series data. This paper presents a time series data mining methodology for temporal knowledge discovery in big BAS data. A number of time series data mining techniques are explored and carefully assembled, including the Symbolic Aggregate approXimation (SAX), motif discovery, and temporal association rule mining. This study also develops two methods for the efficient post-processing of knowledge discovered. The methodology has been applied to analyze the BAS data retrieved from a real building. The temporal knowledge discovered is valuable to identify dynamics, patterns and anomalies in building operations, derive temporal association rules within and between subsystems, assess building system performance and spot opportunities in energy conservation.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Centre for IT-Intelligent Energy Systems in Cities, Hong Kong Polytechnic University
Authors: Fan, C. (Ekstern), Xiao, F. (Ekstern), Madsen, H. (Intern), Wang, D. (Ekstern)
Pages: 75-89
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.

General information

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Scientific Computing, Center for Energy Resources Engineering, Slovak University of Technology, Copenhagen University Hospital
Authors: Bátorá, V. (Ekstern), Tárník, M. (Ekstern), Murgas, J. (Ekstern), Schmidt, S. (Ekstern), Nørgaard, K. (Ekstern), Poulsen, N. K. (Intern), Madsen, H. (Intern), Boiroux, D. (Intern), Jørgensen, J. B. (Intern)
Pages: 5097-5102
Publication date: 2015

Host publication information
Title of host publication: Proceedings of the 2015 American Control Conference (ACC)
Publisher: IEEE
ISBN (Print): 978-1-4799-8685-9
Main Research Area: Technical/natural sciences
Conference: 2015 American Control Conference, Chicago, IL, United States, 01/07/2015 - 01/07/2015
DOIs: 10.1109/ACC.2015.7172134
Publication: Research - peer-review › Article in proceedings – Annual report year: 2015

Thermal Performance Characterization using Time Series Data - IEA EBC Annex 58 Guidelines

This document presents guidelines for using time series analysis methods, models and tools for estimating the thermal performance of buildings and building components. The thermal performance is measured as estimated parameters of a model, or parameters derived from estimated parameters of a model. A special focus will be on estimating the Heat Loss Coefficient (HLC) and gA-value. Provided in the guidelines are modelling procedures with which consistent results for estimation of energy performance of buildings and building components can be achieved.

These guidelines start with simple (non-dynamical) steady state models where the parameters are found using classical methods for linear regression. Such steady state techniques provide sub-optimal use of the information embedded in the data and provides information only about the HLC and gA-values.

Next the guidelines consider dynamical models. Firstly, linear input-output models are considered. More specifically we will consider the class of AutoRegressive with eXogenous input (ARX) (p) models. These models provides information
about the HLC and gA-values, and information about the dynamics (most frequently described as time-constants for the system).

Finally, grey-box models are considered. This class of models is formulated as state space models which are able to provide rather detailed information about the internal physical parameters of a construction. This class of models bridges the gap between physical and statistical modelling. A grey-box model is formulated as a continuous time model for the states of the system, together with a discrete set of equations describing how the measurements are linked to the states. The frequently used so-called RC-network models belongs to the class of linear greybox models. However, advanced constructions, like a wall with PV-integration or a complex building with a lot of glass, often calls for a description of nonlinear phenomena. This can be facilitated by the class of non-linear grey-box models.

It is assumed that data is available as time series of measurements. Hence it should be noticed that the important steps of experimental design and setting up the experiment have been conducted.

**General information**
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, KU Leuven, Ghent University, BBRI
Authors: Madsen, H. (Intern), Bacher, P. (Intern), Bauwens, G. (Ekstern), Deconinck, A. (Ekstern), Reynders, G. (Ekstern), Roels, S. (Ekstern), Himpe, E. (Ekstern), Lethé, G. (Ekstern)
Number of pages: 84
Publication date: 2015

**Publication information**
Publisher: Technical University of Denmark (DTU)
Original language: English
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Electronic versions:
Links:
http://www2.compute.dtu.dk/~pbac/guidelines_DataAndRScripts.zip

**Bibliographical note**
Additional files (data and code) are available via the link.
Publication: Research › Report – Annual report year: 2015

**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.

**General information**
State: Published
Organisations: Department of Wind Energy, Aeroelastic Design, Wind Energy Systems, Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Mirzaei, M. (Intern), Göçmen Bozkurt, T. (Intern), Giebel, G. (Intern), Sørensen, P. E. (Intern), Poulsen, N. K. (Intern)
Pages: 1709 - 1714
Publication date: 2015

**Host publication information**
Title of host publication: Proceedings of 2015 American Control Conference
A Comparison between Two Simulation Models for Spread of Foot-and-Mouth Disease

Two widely used simulation models of foot-and-mouth disease (FMD) were used in order to compare the models’ predictions in term of disease spread, consequence, and the ranking of the applied control strategies, and to discuss the effect of the way disease spread is modeled on the predicted outcomes of each model. The DTU-DADS (version 0.100), and ISP (version 2.001.11) were used to simulate a hypothetical spread of FMD in Denmark. Actual herd type, movements, and location data in the period 1st October 2006 and 30th September 2007 was used. The models simulated the spread of FMD using 3 different control scenarios: 1) A basic scenario representing EU and Danish control strategies, 2) pre-emptive depopulation of susceptible herds within a 500 meters radius around the detected herds, and 3) suppressive vaccination of susceptible herds within a 1,000 meters radius around the detected herds. Depopulation and vaccination started 14 days following the detection of the first infected herd. Five thousand index herds were selected randomly, of which there were 1,000 cattle herds located in high density cattle areas and 1,000 in low density cattle areas, 1,000 swine herds located in high density swine areas and 1,000 in low density swine areas, and 1,000 sheep herds. Generally, DTU-DADS predicted larger, longer duration and costlier epidemics than ISP, except when epidemics started in cattle herds located in high density cattle areas. ISP supported suppressive vaccination rather than pre-emptive depopulation, while DTU-DADS was indifferent to the alternative control strategies. Nonetheless, the absolute differences between control strategies were small making the choice of control strategy during an outbreak to be most likely based on practical reasons.
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.

General information
State: Published
Organisations: Department of Electrical Engineering, Automation and Control, Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Niemann, H. H. (Intern), Poulsen, N. K. (Intern)
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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.

General information
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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 $\ell_1$-regularization term. In the presence of process and measurement noise, such a regularization term is critical for achieving a well-behaved closed-loop performance.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems, Center for Energy Resources Engineering, DONG Energy A/S
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Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.521 SNIP 2.735 CiteScore 3.92
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.507 SNIP 2.607 CiteScore 3.47
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.563 SNIP 2.954 CiteScore 3.39
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.316 SNIP 2.59 CiteScore 2.9
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.305 SNIP 2.203
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.282 SNIP 2.772
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.458 SNIP 2.698
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.

General information
State: Published
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A Decomposition Algorithm for Mean-Variance Economic Model Predictive Control of Stochastic Linear Systems

This paper presents a decomposition algorithm for solving the optimal control problem (OCP) that arises in Mean-Variance Economic Model Predictive Control of stochastic linear systems. The algorithm applies the alternating direction method of multipliers to a reformulation of the OCP that decomposes into small independent subproblems. We test the decomposition algorithm using a simple power management case study, in which the OCP is formulated as a convex quadratic program. Simulations show that the decomposition algorithm scales linearly in the number of uncertainty scenarios. Moreover, a parallel implementation of the algorithm is several orders of magnitude faster than state-of-the-art convex quadratic programming algorithms, provided that the number of uncertainty scenarios is large.

General information
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A finite-element method model for droplets moving down a hydrophobic surface

We set up a 2D computational Finite-Element Method (FEM) model describing the initial descent of a droplet down an inclined hydrophobic substrate. We solve the full Navier-Stokes equations inside the drop domain, and use the arbitrary Lagrangian-Eulerian method to keep track of the droplet surface. The contact angle is included by using the Frennet-Serret equations. We investigate the behaviour of the drop velocity as a function of the slip length and compare with experimental results. Furthermore, we quantify the energy associated with centre-of-mass translation and internal fluid motion, and we also compute the local dissipation of energy inside the drop. The model predicts trajectories for tracer particles deposited inside the drop, and satisfactorily describes the sliding motion of steadily accelerating droplets. The model can be used for determining a characteristic slip parameter, associated with slip lengths and drag reduction for hydrophobic surfaces.
A Mean-Variance Criterion for Economic Model Predictive Control of Stochastic Linear Systems

Stochastic linear systems arise in a large number of control applications. This paper presents a mean-variance criterion for economic model predictive control (EMPC) of such systems. The system operating cost and its variance is approximated based on a Monte-Carlo approach. Using convex relaxation, the tractability of the resulting optimal control problem is addressed. We use a power management case study to compare different variations of the mean-variance strategy with EMPC based on the certainty equivalence principle. The certainty equivalence strategy is much more computationally efficient than the mean-variance strategies, but it does not account for the variance of the uncertain parameters. Openloop simulations suggest that a single-stage mean-variance approach yields a significantly lower operating cost than the certainty equivalence strategy. In closed-loop, the single-stage formulation is overly conservative, which results in a high operating cost. For this case, a two-stage extension of the mean-variance approach provides the best trade-off between the expected cost and its variance. It is demonstrated that by using a constraint back-off technique in the specific case study, certainty equivalence EMPC can be modified to perform almost as well as the two-stage mean-variance formulation. Nevertheless, we argue that the mean-variance approach can be used both as a strategy for evaluating less computational demanding methods such as the certainty equivalence method, and as an individual control strategy when heuristics such as constraint back-off do not perform well.
A model predictive control strategy for the space heating of a smart building including cogeneration of a fuel cell-electrolyzer system

The objective of this paper is to analyze the value of energy replacement in the context of demand response. Energy replacement is dened as the possibility of the consumer to choose the most convenient source for providing space heating to a smart building according to a dynamic electricity price. In the proposed setup, heat is provided by conventional electric radiators and a combined heat and power generation system, composed by a fuel cell and an electrolyzer. The energy replacement strategy is formulated using model predictive control and mathematical models of the components involved. Simulations show that the predictive energy replacement strategy reduces the operating costs of the system and is able to provide a larger amount of regulating power to the grid. In the paper, we also develop a novel dynamic model of a PEM fuel cell suitable for micro-grid applications. The model is realized applying a grey-box methodology to the experimental proton exchange membrane fuel cell of the EPFL-DESL micro-grid.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Electric Power and Energy, Department of Applied Mathematics and Computer Science, Dynamical Systems, Ecole Polytechnique Federale de Lausanne (EPFL)
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BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.3 SJR 1.562 SNIP 1.785
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.548 SNIP 2.052 CiteScore 3.97
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.436 SNIP 2.343 CiteScore 4.34
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.357 SNIP 2.754 CiteScore 4.54
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.239 SNIP 2.799 CiteScore 4.37
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.078 SNIP 2.342 CiteScore 3.46
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.065 SNIP 2.263
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.262 SNIP 1.846
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.668 SNIP 1.026
An Iterative Method for the Approximation of Fibers in Slow-Fast Systems

In this paper we extend a method for iteratively improving slow manifolds so that it also can be used to approximate the fiber directions. The extended method is applied to general finite-dimensional real analytic systems where we obtain exponential estimates of the tangent spaces to the fibers. The method is demonstrated on the Michaelis–Menten–Henri model and the Lindemann mechanism. The latter example also serves to demonstrate the method on a slow-fast system in nonstandard slow-fast form. Finally, we extend the method further so that it also approximates the curvature of the fibers.
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.
Automatic Classification of Offshore Wind Regimes With Weather Radar Observations

Weather radar observations are called to play an important role in offshore wind energy. In particular, they can enable the monitoring of weather conditions in the vicinity of large-scale offshore wind farms and thereby notify the arrival of precipitation systems associated with severe wind fluctuations. The information they provide could then be integrated into an advanced prediction system for improving offshore wind power predictability and controllability. In this paper, we address the automatic classification of offshore wind regimes (i.e., wind fluctuations with specific frequency and amplitude) using reflectivity observations from a single weather radar system. A categorical sequence of most likely wind regimes is estimated from a wind speed time series by combining a Markov-Switching model and a global decoding technique, the Viterbi algorithm. In parallel, attributes of precipitation systems are extracted from weather radar images. These attributes describe the global intensity, spatial continuity and motion of precipitation echoes on the images. Finally, a CART classification tree is used to find the broad relationships between precipitation attributes and wind regimes.
Benefits and challenges of electrical demand response: A critical review

Advances in IT, control and forecasting capabilities have made demand response a viable, and potentially attractive, option to increase power system flexibility. This paper presents a critical review of the literature in the field of demand response, providing an overview of the benefits and challenges of demand response. These benefits include the ability to balance fluctuations in renewable generation and consequently facilitate higher penetrations of renewable resources on
the power system, an increase in economic efficiency through the implementation of real-time pricing, and a reduction in
generation capacity requirements. Nevertheless, demand response is not without its challenges. The key challenges for
demand response centre around establishing reliable control strategies and market frameworks so that the demand
response resource can be used optimally. One of the greatest challenges for demand response is the lack of experience,
and the consequent need to employ extensive assumptions when modelling and evaluating this resource. This paper
concludes with an examination of these assumptions, which range from assuming a fixed linear price–demand relationship
for price responsive demand, to modelling the highly diverse, distributed and uncertain demand response resource as a
single, centralised negative generator, adopting fixed characteristics and constraints.

General information
State: Published
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Scopus rating (2016): CiteScore 9.52 SJR 3.051 SNIP 3.454
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2.999 SNIP 3.387 CiteScore 8.35
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 3.106 SNIP 3.761 CiteScore 7.79
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 3.072 SNIP 3.889 CiteScore 7.88
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.814 SNIP 3.915 CiteScore 7.24
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 2.787 SNIP 3.901 CiteScore 7.39
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 2.374 SNIP 3.112
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 2.494 SNIP 3.6
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 2.447 SNIP 3.127
Web of Science (2008): Indexed yes
Scopus rating (2006): SJR 0.889 SNIP 1.758
Bifurcation analysis of a smoothed model of a forced impacting beam and comparison with an experiment

A piecewise-linear model with a single degree of freedom is derived from first principles for a driven vertical cantilever beam with a localized mass and symmetric stops. The aim is to show that this model constitutes a considerable step toward developing a vibro-impact model that is able to make qualitative and quantitative predictions of the observed dynamics. The resulting piecewise-linear dynamical system is smoothed by a switching function (nonlinear homotopy). For the chosen smoothing function, it is shown that the smoothing can induce bifurcations in certain parameter regimes. These induced bifurcations disappear when the transition of the switching is sufficiently and increasingly localized as the impact becomes harder. The bifurcation structure of the impact oscillator response is investigated via the one- and two-parameter continuation of periodic orbits in the driving frequency and/or forcing amplitude. The results are in good agreement with experimental measurements.

General information
State: Published
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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.423 SNIP 1.533 CiteScore 3.06
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.235 SNIP 1.73 CiteScore 3.07
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.214 SNIP 1.638 CiteScore 2.85
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 0.9 SNIP 1.938 CiteScore 2.83
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 2
Bifurcation of learning and structure formation in neuronal maps

Most learning processes in neuronal networks happen on a much longer time scale than that of the underlying neuronal dynamics. It is therefore useful to analyze slowly varying macroscopic order parameters to explore a network’s learning ability. We study the synaptic learning process giving rise to map formation in the laminar nucleus of the barn owl's auditory system. Using equation-free methods, we perform a bifurcation analysis of spatio-temporal structure formation in the associated synaptic-weight matrix. This enables us to analyze learning as a bifurcation process and follow the unstable states as well. A simple time translation of the learning window function shifts the bifurcation point of structure formation and goes along with traveling waves in the map, without changing the animal's sound localization performance.

General information
State: Published
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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.
Characterization of heat dynamics of an arctic low-energy house with floor heating

This paper presents grey-box modeling of the heat dynamics of an apartment in a highly insulated test building located in the Arctic. Data from a 16-day-long experiment is analyzed and used to fit lumped parameter models formulated as coupled stochastic differential equations. The output of the models is the measured indoor air temperature, and the models are fitted using maximum likelihood techniques with the software CTSM-R. Models are compared using likelihood-ratio tests and validated considering autocorrelation and periodograms of residuals. The fitted models facilitate description of both the fast responses to mechanical ventilation and solar radiation through a large window facade, and the slow responses to floor heating and outdoor temperature. To successfully describe the dynamics of the system, solar radiation is given special attention in modeling of both the physical system and the observational noise. The estimated physical parameters which include UA-value, total heat capacity, and time constants for the apartment are discussed. Simulations are performed to illustrate step and impulse responses of inputs.

General information
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Organisations: Department of Applied Mathematics and Computer Science , Dynamical Systems, Department of Civil Engineering, Section for Indoor Environment, Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
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Number of pages: 20
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Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 1.56 SJR 0.784 SNIP 0.936
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.016 SNIP 1.154 CiteScore 1.74
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.827 SNIP 1.264 CiteScore 1.41
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.45 SNIP 0.649 CiteScore 0.77
ISI indexed (2013): ISI indexed yes
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BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.444 SNIP 0.751 CiteScore 0.72
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 0.373 SNIP 0.858 CiteScore 0.95
ISI indexed (2011): ISI indexed no
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CITIES: Centre for IT-Intelligent Energy Systems in Cities
This extended abstract provides an introduction to an interdisciplinary strategic research project, CITIES which has been funded with an excess of € 7 million from a wide range of industrial and academic partners, and the Danish Council for Strategic Research. CITIES was launched January 1, 2014 and aims at developing methodologies and ICT solutions for the analysis, operation, planning and development of fully integrated urban energy systems. A holistic research approach will be developed, to provide solutions at all levels between the appliance and the overall system, and at all-time scales between operations and planning. This extended abstract outlines the challenges to be met by city and energy planning bodies in an energy efficient future. The necessity of novel, data driven and IT intelligent solutions is stressed. A focus is placed on energy system planning in systems with high penetrations of renewable energy, or those entirely independent of fossil fuels.

**General information**
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Organisations: Department of Management Engineering, Systems Analysis, DTU Climate Centre, Energy Systems Analysis, Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Civil Engineering, Section for Building Physics and Services, Centre for IT-Intelligent Energy Systems in Cities
Authors: Herrmann, I. T. (Intern), O'Connell, N. (Intern), Heller, A. (Intern), Madsen, H. (Intern)
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Publication date: 2014

**Coarse Analysis of Microscopic Models using Equation-Free Methods**
Mathematical models of real-world problems from physics, biology and chemistry have become very complex over the last three decades. Although increasing computational power allows to solve even larger systems of differential equations, the number of differential equations is still a main limiting factor for the complexity of models, e.g., in real-time applications. With the increasing amount of data generated by computer simulations a challenge is to extract valuable information from the models in order to help scientists and managers in a decision-making process. Although the dynamics of these models might be high-dimensional, the properties of interest are usually macroscopic and low-dimensional in nature. Examples are numerous and not necessarily restricted to computer models. For instance, the power output, energy consumption and temperature of engines are interesting quantities for engineers, although the models they base their design on are described for the gas mixture (a system with many degrees-of-freedom) inside a combustion engine. Since good models are often not available on the macroscopic scale the necessary information has to be extracted from the microscopic, high-dimensional models.

The goal of this thesis is to investigate such high-dimensional multiscale models and extract relevant low-dimensional information from them. Recently developed mathematical tools allow to reach this goal: a combination of so-called equation-free methods with numerical bifurcation analysis is used and further developed to gain insight into high-dimensional systems on a macroscopic level of interest. Based on a switching-procedure between a detailed microscopic and a coarse macroscopic level during simulations it is possible to obtain a closure-on-demand for the macroscopic dynamics by only using short simulation bursts of computationally-expensive complex models. Those information is subsequently used to construct bifurcation diagrams that show the parameter dependence of solutions of the system.

The methods developed for this thesis have been applied to a wide range of relevant problems. Applications include the learning behavior in the barn owl’s auditory system, traffic jam formation in an optimal velocity model for circular car traffic and oscillating behavior of pedestrian groups in a counter-flow through a corridor with narrow door. The methods do not only quantify interesting properties in these models (learning outcome, traffic jam density, oscillation period), but also allow to investigate unstable solutions, which are important information to determine basins of attraction of stable solutions and thereby reveal information on the long-term behavior of an initial state.

**General information**
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Coarse-grained particle model for pedestrian flow using diffusion maps
Interacting particle systems constitute the dynamic model of choice in a variety of application areas. A prominent example
is pedestrian dynamics, where good design of escape routes for large buildings and public areas can improve evacuation
in emergency situations, avoiding exit blocking and the ensuing panic. Here we employ diffusion maps to study the
coarse-grained dynamics of two pedestrian crowds trying to pass through a door from opposite sides. These macroscopic
variables and the associated smooth embeddings lead to a better description and a clearer understanding of the nature of
the transition to oscillatory dynamics. We also compare the results to those obtained through intuitively chosen
macroscopic variables.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Princeton University
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Coarse-grained particle model for pedestrian flow using diffusion maps
Interacting particle systems constitute the dynamic model of choice in a variety of application areas. A prominent example
is pedestrian dynamics, where good design of escape routes for large buildings and public areas can improve evacuation
in emergency situations, avoiding exit blocking and the ensuing panic. Here we employ diffusion maps to study the
coarse-grained dynamics of two pedestrian crowds trying to pass through a door from opposite sides. These macroscopic
variables and the associated smooth embeddings lead to a better description and a clearer understanding of the nature of
the transition to oscillatory dynamics. We also compare the results to those obtained through intuitively chosen
macroscopic variables.
CONTINEX: A Toolbox for Continuation in Experiments

CONTINEX is a MATLAB toolbox for bifurcation analysis based on the development platform COCO (computational continuation core). CONTINEX is specifically designed for coupling to experimental test specimen via DSPACE, but provides also interfaces to SIMULINK-, ODE-, and so-called equation-free models. The current version of the interface for experimental set-ups implements an algorithm for tuning control parameters, a robust noise-tolerant covering algorithm, and functions for monitoring (in)stability. In this talk we will report on experiments with an impact oscillator with magnetic actuators and algorithmic challenges we were facing during toolbox development.
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.

Determing reserve requirements in DK1 area of Nord Pool using a probabilistic approach
Allocation of electricity reserves is the main tool for transmission system operators to guarantee a reliable and safe real-time operation of the power system. Traditionally, a deterministic criterion is used to establish the level of reserve. Alternative criteria are given in this paper by using a probabilistic framework where the reserve requirements are computed based on scenarios of wind power forecast error, load forecast errors and power plant outages. Our approach is first motivated by the increasing wind power penetration in power systems worldwide as well as the current market design of the DK1 area of Nord Pool, where reserves are scheduled prior to the closure of the day-ahead market. The risk of the solution under the resulting reserve schedule is controlled by two measures: the LOLP (Loss-of-Load Probability) and the CVaR (Conditional Value at Risk). Results show that during the case study period, the LOLP methodology produces more costly and less reliable reserve schedules, whereas the solution from the CVaR-method increases the safety of the overall system while decreasing the associated reserve costs, with respect to the method currently used by the Danish TSO (Transmission System Operator).

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Discussion of "Prediction intervals for short-term wind farm generation forecasts" and "Combined nonparametric prediction intervals for wind power generation"

A new score for the evaluation of interval forecasts, the so-called coverage width-based criterion (CWC), was proposed and utilized. This score has been used for the tuning (in-sample) and genuine evaluation (out-of-sample) of prediction intervals for various applications, e.g., electric load [1], electricity prices [2], general purpose prediction [3], and wind power generation [4], [5]. Indeed, two papers by the same authors appearing in the IEEE Transactions On Sustainable Energy employ that score and use it to conclude on the comparative quality of alternative approaches to interval forecasting of wind power generation.
Drops on hydrophobic surfaces & vibrated fluid surfaces

The first part of this thesis deals with a droplet on a hydrophobic surface. We first present a basic introduction to fluid dynamics, including a description of relevant dimensionless numbers and a derivation of the Young-Laplace equation. An analytic approach to describing the oscillations of a droplet is then given, after which we set up a 2D computational Finite-Element Method (FEM) model for a neutrally buoyant drop immersed in another liquid. The model is validated by considering the volume loss over time.

Subsequent to an introduction to the physics of wetting, the developed FEM model is then extended to include drop-surface interactions, and we describe a) the initial descent of a droplet down an inclined hydrophobic substrate, and b) the motion of the droplet in a potential well created through spatial contact angle variations. We solve the full Navier-Stokes equations inside the drop domain, and use the Arbitrary Lagrangian-Eulerian method to keep track of the droplet surface; the contact angle is included by using the Frennet-Serret equations.

In situation a), we investigate the behavior of the drop velocity as a function of the slip length and compare with experimental results found in the literature. Furthermore, we quantify the energy associated with center of mass translation and internal fluid motion. The model predicts trajectories for tracer particles deposited inside the drop, and satisfactorily describes the sliding motion of steadily accelerating droplets. The model can be used for determining a characteristic slip parameter, associated with slip lengths and drag reduction for hydrophobic surfaces.

In situation b), we observe that the droplet oscillations (frequency, amplitude and decay time) in the potential is not linear with respect to the forcing, i.e. the strength of the potential, and contribute this to preferred eigenmodes of the droplet oscillation.

The second part of this thesis deals with a droplet bouncing on a vertically vibrated fluid bath of the same liquid, a system which is the first known macroscopic example of pilot-wave dynamics. An introduction to the experimental set-up is given, followed by a description of the mathematical models governing the vertical and horizontal motion of the drop. Two in-depth studies are then presented.

In the first, the results of a comprehensive series of experiments are presented. The most detailed characterisation to date of the system’s dependence on fluid properties, droplet size, and vibrational forcing is provided. A number of new bouncing and walking states are reported, including complex periodic and aperiodic motions. Specific attention is given to the first characterisation of the different gaits arising within the walking regime. In addition to complex periodic walkers and limping droplets, we highlight a previously unreported mixed state, in which the droplet switches periodically between two distinct walking modes. The experimental results are compared to previously developed theoretical predictions.

In the second study, wo consider the case where the fluid bath is also rotated around its center-line. The drop then experiences an effective Coriolis force, and previous studies have made a comparison between emerging unstable radii in this system and Landau levels for a charged particle in a magnetic field. The system is treated numerically, and the results are compared to experiments. We provide, again, the most detailed regime diagram of the possible orbits depending on the forcing and the rotation rate of the fluid bath. We highlight each class of orbit, and analyze in depth the wobbling state, precessing orbits, wobble-leap dynamics, exotic trajectories and the emergence of statistical behavior when the forcing is near the Faraday threshold.
Dynamic modeling of presence of occupants using inhomogeneous Markov chains

Occupancy modeling is a necessary step towards reliable simulation of energy consumption in buildings. This paper outlines a method for fitting recordings of presence of occupants and simulation of single-person to multiple-persons office environments. The method includes modeling of dependence on time of day, and by use of a filter of the observations it is able to capture per-employee sequence dynamics. Simulations using this method are compared with simulations using homogeneous Markov chains and show far better ability to reproduce key properties of the data. The method is based on inhomogeneous Markov chains with where the transition probabilities are estimated using generalized linear models with polynomials, B-splines, and a filter of passed observations as inputs. For treating the dispersion of the data series, a hierarchical model structure is used where one model is for low presence rate, and another is for high presence rate.

General information
State: Published
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Scopus rating (2013): SJR 1.897 SNIP 2.433 CiteScore 3.79
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Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.624 SNIP 2.028
Web of Science (2008): Indexed yes
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.
Electricity market clearing with improved dispatch of stochastic production

In this paper, we consider an electricity market that consists of a day-ahead and a balancing settlement, and includes a number of stochastic producers. We first introduce two reference procedures for scheduling and pricing energy in the day-ahead market: on the one hand, a conventional network-constrained auction purely based on the least-cost merit order, where stochastic generation enters with its expected production and a low marginal cost; on the other, a counterfactual auction that also accounts for the projected balancing costs using stochastic programming. Although the stochastic clearing procedure attains higher market efficiency in expectation than the conventional day-ahead auction, it suffers from fundamental drawbacks with a view to its practical implementation. In particular, it requires flexible producers (those that make up for the lack or surplus of stochastic generation) to accept losses in some scenarios. Using a bilevel programming framework, we then show that the conventional auction, if combined with a suitable day-ahead dispatch of stochastic producers (generally different from their expected production), can substantially increase market efficiency and emulate the advantageous features of the stochastic optimization ideal, while avoiding its major pitfalls.

A two-node power system serves as both an illustrative example and a proof of concept. Finally, a more realistic case study highlights the main advantages of a smart day-ahead dispatch of stochastic producers.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Electrical Engineering, Center for Electric Power and Energy, Technical University of Denmark
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BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.334 SNIP 2.412 CiteScore 3.59
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.186 SNIP 2.485 CiteScore 3.21
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
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ISI indexed (2013): ISI indexed yes
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BFI (2012): BFI-level 1
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BFI (2011): BFI-level 1
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ISI indexed (2011): ISI indexed yes
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Scopus rating (2010): SJR 2.477 SNIP 2.435
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Equation-Free Analysis of Macroscopic Behavior in Traffic and Pedestrian Flow

Equation-free methods make possible an analysis of the evolution of a few coarse-grained or macroscopic quantities for a detailed and realistic model with a large number of fine-grained or microscopic variables, even though no equations are explicitly given on the macroscopic level. This will facilitate a study of how the model behavior depends on parameter values including an understanding of transitions between different types of qualitative behavior. These methods are introduced and explained for traffic jam formation and emergence of oscillatory pedestrian counter flow in a corridor with a narrow door.

General information
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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 effect 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.

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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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BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.204 SNIP 0.165 CiteScore 0.17
ISI indexed (2012): ISI indexed no
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Scopus rating (2009): SJR 0.111 SNIP 0.032
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Scopus rating (2004): SJR 0.106 SNIP 0.017
Scopus rating (2003): SJR 0.101 SNIP 0.01
Evaluation of Dynamical Downscaling Resolution Effect on Wind Energy Forecast Value for a Wind Farm in Central Sweden

For any energy system relying on wind power, accurate forecasts of wind fluctuations are essential for efficient integration into the power grid. Increased forecast precision allows end-users to plan day-ahead operation with reduced risk of penalties which in turn supports the feasibility of wind energy. The present study aims to quantify value added to wind energy forecasts in the 12-48 hour leadtime by downscaling global numerical weather prediction (NWP) data from the National Centers for Environmental Prediction Global Forecast System (GFS) using the limited-area NWP model described in Skamarock et al. (2008).

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Organisations: Department of Wind Energy, Meteorology, Wind Energy Systems, Department of Applied Mathematics and Computer Science, Dynamical Systems, ENFOR A/S
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Evaluation of Dynamical Downscaling Resolution Effect on Wind Energy Forecast Value for a Wind Farm in Central Sweden

For any energy system relying on wind power, accurate forecasts of wind fluctuations are essential for efficient utilisation in the power grid. Statistical wind power prediction tools [1] use numerical weather prediction (NWP) model data along with measurements and can correct magnitude errors operationally. It is, however, entirely up to the NWP input to describe the timing of fluctuations correctly.

Wind power is nonlinearly transformed wind speed, and the two are monotonically dependent up till wind speeds of ~25m/s, which is the typical wind farm cut-out. Thus, an improvement in the correlation accuracy metric evaluated for wind speed data consistently translates to an improvement for wind power. For two time series describing the temporal development of the same variable, though by different means, it is assumed that phase errors account for most of the departure from perfect correlation between the two time series.

Results on limited-area NWP model performance, with focus on the 12th to 48th forecast hour horizon relevant for Elspot auction bidding on the Nord Pool Spot market [2], are presented.

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Evaluation of Dynamical Downscaling Resolution Effect on Wind Energy Forecast Value for a Wind Farm in Central Sweden

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Experimental bifurcation analysis of an impact oscillator – Determining stability
We propose and investigate three different methods for assessing stability of dynamical equilibrium states during experimental bifurcation analysis, using a control-based continuation method. The idea is to modify or turn off the control at an equilibrium state and study the resulting behavior. As a proof of concept the three methods are successfully implemented and tested for a harmonically forced impact oscillator with a hardening spring nonlinearity, and controlled by electromagnetic actuators. We show that under certain conditions it is possible to quantify the instability in terms of finite-time Lyapunov exponents. As a special case we study an isolated branch in the bifurcation diagram brought into existence by a 1:3 subharmonic resonance. On this isola it is only possible to determine stability using one of the three methods, which is due to the fact that only this method guarantees that the equilibrium state can be restored after measuring stability.

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Organisations: Department of Mechanical Engineering, Department of Applied Mathematics and Computer Science, Dynamical Systems, Mathematics, Solid Mechanics
Authors: Bureau, E. (Intern), Schilder, F. (Intern), Elmegård, M. (Intern), Santos, I. (Intern), Thomsen, J. J. (Intern), Starke, J. (Intern)
Experimental Bifurcation Analysis Using Control-Based Continuation

The focus of this thesis is developing and implementing techniques for performing experimental bifurcation analysis on nonlinear mechanical systems. The research centers around the newly developed control-based continuation method, which allows to systematically track branches of stable and unstable equilibria under variation of parameters. As a test case we demonstrate that it is possible to track the complete frequency response, including the unstable branches, for a harmonically forced impact oscillator with hardening spring nonlinearity, controlled by electromagnetic actuators. The method requires the constitution of a non-invasive and locally stabilizing control scheme, which must be tuned without a-priori study of a model. We propose a sequence of experiments that allows to choose optimal control-gains, filter parameters and settings for a continuation method. This experimental tuning procedure is applied to our test rig, resulting in a reliable non-invasive, locally stabilizing control. The use of stabilizing control makes it difficult to determine the stability of the underlying uncontrolled equilibrium. Based on the idea of momentarily modifying or disabling the control and study the resulting behavior, we propose and test three different methods for assessing stability of equilibrium states during experimental continuation. We show that it is possible to determine the stability without allowing unbounded divergence, and that it is under certain circumstances possible to quantify instability in terms of finite-time Lyapunov exponents. A software toolbox for the Matlab continuation platform COCO has been developed and will be made freely available. This toolbox implements functions necessary for interfacing a numerical continuation code with a real experiment, as well as provide means for simulating control-based continuation experiments. Finally, the feasibility of implementing the method for rotating machinery is discussed.

Experiments in nonlinear dynamics using control-based continuation: Tracking stable and unstable response curves

We show how to implement control-based continuation in a nonlinear experiment using existing and freely available software. We demonstrate that it is possible to track the complete frequency response, including the unstable branches, for a harmonically forced impact oscillator.

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Experiments in nonlinear dynamics using control-based continuation: Tracking stable and unstable response curves

We show how to implement control-based continuation in a nonlinear experiment using existing and freely available software. We demonstrate that it is possible to track the complete frequency response, including the unstable branches, for a harmonically forced impact oscillator.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Mechanical Engineering, Solid Mechanics
Authors: Bureau, E. (Intern), Schilder, F. (Intern), Santos, I. (Intern), Thomsen, J. J. (Intern), Starke, J. (Intern)
Exponential smoothing approaches for prediction in real-time electricity markets

The optimal design of offering strategies for wind power producers is commonly based on unconditional (and, hence, constant) expectation values for prices in real-time markets, directly defining their loss function in a stochastic optimization framework. This is why it may certainly be advantageous to account for the seasonal and dynamic behavior of such prices, hence translating to time-varying loss functions. With that objective in mind, forecasting approaches relying on simple models that accommodate the seasonal and dynamic nature of real-time prices are derived and analyzed. These are all based on the well-known Holt–Winters model with a daily seasonal cycle, either in its conventional form or conditioned upon exogenous variables, such as: (i) day-ahead price; (ii) system load; and (iii) wind power penetration. The superiority of the proposed approach over a number of common benchmarks is subsequently demonstrated through an empirical investigation for the Nord Pool, mimicking practical forecasting for a three-year period over 2008–2011.
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.
How Fitness Reduced, Antimicrobial Resistant Bacteria Survive and Spread: A Multiple Pig - Multiple Bacterial Strain Model

More than 30% of E. coli strains sampled from pig farms in Denmark over the last five years were resistant to the commonly used antimicrobial tetracycline. This raises a number of questions: How is this high level sustained if resistant bacteria have reduced growth rates? Given that there are multiple susceptible and resistant bacterial strains in the pig intestines, how can we describe their coexistence? To what extent does the composition of these multiple strains in individual pigs influence the total bacterial population of the pig pen? What happens to a complex population when antimicrobials are used? To investigate these questions, we created a model where multiple strains of bacteria coexist in the intestines of pigs sharing a pen, and explored the parameter limits of a stable system; both with and without an antimicrobial treatment. The approach taken is a deterministic bacterial population model with stochastic elements of bacterial distributions and transmission. The rates that govern the model are process-oriented to represent growth, excretion, and uptake from environment, independent of herd and meta-population structures. Furthermore, an entry barrier and elimination process for the individual strains in each pig were implemented. We demonstrate how competitive growth between multiple bacterial strains in individual pigs, and the transmission between pigs in a pen allow for strains of antimicrobial resistant bacteria to persist in a pig population to different extents, and how quickly they can become dominant if antimicrobial treatment is initiated. The level of spread depends in a non-linear way of the parameters that govern excretion and uptake. Furthermore, the sampling of initial distributions of strains and stochastic transmission events give rise to large variation in how homogenous and how resistant the bacterial population becomes. Most important: resistant bacteria are demonstrated to survive with a disadvantage in growth rate of well over 10%.
iCull - a herd-specific tool for financial evaluation of the impact of paratuberculosis

**General information**

**State:** Published  
**Organisations:** National Veterinary Institute, Section for Epidemiology, Department of Applied Mathematics and Computer Science, Dynamical Systems, University of Copenhagen  
**Authors:** Kirkeby, C. (Intern), Hisham Beshara Halasa, T. (Intern), Nielsen, S. S. (Ekstern), Græsbøll, K. (Intern), Toft, N. (Intern)  
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IEA Common Exercise 4: ARX, ARMAX and grey-box models for thermal performance characterization of the test box

In this report results of applying time series models for assessing the thermal performance of the IEA Annex 58 test box based on data given in the Common Exercise 4 (CE4), which was measured in Almeria, Spain. Both ARX, ARMAX and grey-box models are applied. Finally, the same models are fitted for the Common Exercise 3b (CE3) data measured in Belgium and the results are compared.

The focus in this report is on model selection and validation enabling a stable and reliable performance assessment. Basically, the challenge is to find a procedure for each type of model, which can give un-biased and accurate estimates of the essential performance parameters, including reliable uncertainties of the estimates. Important is also the development of methodologies for analyzing the quality of data, for example correlated inputs and lack of information in data (e.g. if no clearsky days with direct solar radiation is present data), these aspects are discussed. Furthermore, new models for enhancing the description of the effect of solar radiation on the test box is presented.

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**Organisations:** Department of Applied Mathematics and Computer Science, Dynamical Systems  
**Authors:** Bacher, P. (Intern), Andersen, P. H. D. (Intern)  
**Number of pages:** 49  
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**Main Research Area:** Technical/natural sciences
Implicit methods for equation-free analysis: convergence results and analysis of emergent waves in microscopic traffic models

We introduce a general formulation for an implicit equation-free method in the setting of slow-fast systems. First, we give a rigorous convergence result for equation-free analysis showing that the implicitly defined coarse-level time stepper converges to the true dynamics on the slow manifold within an error that is exponentially small with respect to the small parameter measuring time scale separation. Second, we apply this result to the idealized traffic modeling problem of phantom jams generated by cars with uniform behavior on a circular road. The traffic jams are waves that travel slowly against the direction of traffic. Equation-free analysis enables us to investigate the behavior of the microscopic traffic model on a macroscopic level. The standard deviation of cars’ headways is chosen as the macroscopic measure of the underlying dynamics such that traveling wave solutions correspond to equilibria on the macroscopic level in the equation-free setup. The collapse of the traffic jam to the free flow then corresponds to a saddle-node bifurcation of this macroscopic equilibrium. We continue this bifurcation in two parameters using equation-free analysis.

General Information
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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, University of Exeter, AKAD University of Applied Sciences, Toyota Central Research & Development Laboratories, Inc.
Authors: Marschler, C. (Intern), Sieber, J. (Ekstern), Berkemer, R. (Intern), Kawamoto, A. (Intern), Starke, J. (Intern)
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ISI indexed (2011): ISI indexed yes
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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. 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.

**General information**

State: Published  
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, National Space Institute, Sonardyne International Ltd., Technical University of Denmark  
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**Integrating Renewables in Electricity Markets: Operational Problems**

This addition to the ISOR series addresses the analytics of the operations of electric energy systems with increasing penetration of stochastic renewable production facilities, such as wind- and solar-based generation units.  

As stochastic renewable production units become ubiquitous throughout electric energy systems, an increasing level of flexible backup provided by non-stochastic units and other system agents is needed if supply security and quality are to be maintained.  

Within the context above, this book provides up-to-date analytical tools to address challenging operational problems such as:
• The modeling and forecasting of stochastic renewable power production.
• The characterization of the impact of renewable production on market outcomes.
• The clearing of electricity markets with high penetration of stochastic renewable units.
• The development of mechanisms to counteract the variability and unpredictability of stochastic renewable units so that supply security is not at risk.
• The trading of the electric energy produced by stochastic renewable producers.
• The association of a number of electricity production facilities, stochastic and others, to increase their competitive edge in the electricity market.
• The development of procedures to enable demand response and to facilitate the integration of stochastic renewable units.

This book is written in a modular and tutorial manner and includes many illustrative examples to facilitate its comprehension. It is intended for advanced undergraduate and graduate students in the fields of electric energy systems, applied mathematics and economics. Practitioners in the electric energy sector will benefit as well from the concepts and techniques explained in this book.

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Mathematical Modeling and Dimension Reduction in Dynamical Systems
Processes that change in time are in mathematics typically described by differential equations. These may be applied to model everything from weather forecasting, brain patterns, reaction kinetics, water waves, finance, social dynamics, structural dynamics and electrodynamics to name only a few. These systems are generically nonlinear and the studies of them often become enormously complex. The framework in which such systems are best understood is via the theory of dynamical systems, where the critical behavior is systematically analyzed by performing bifurcation theory. In that context the current thesis is attacking two problems.

The first is concerned with the mathematical modelling and analysis of an experiment of a vibro-impacting beam. This type of dynamical system has received much attention in the recent years and they occur frequently in mechanical applications, where they induce noise and wear which decrease the life time of machines. From the modelling point of view these systems are often particularly rich in nonlinear dynamics. In the present study a mathematical model is derived. Amongst other outcomes the model was successfully applied to predict a nonlinear phenomenon, namely the existence of isolas of subharmonic orbits. These were then verified in the practical experiment in the lab. The second problem that is addressed in the current thesis is a problem that has developed as a consequence of the increasing power of computers which has created the demand for analysis of ever more advanced and complex systems. These complex systems are computationally very demanding and proper analysis of the qualitative behavior of the systems becomes difficult. In general it is not possible to construct bifurcation diagrams for these so-called high-dimensional models efficiently. In order to overcome this obstacle much research is going into the direction of development of robust methods to perform dimension and model reduction such as to pave the way for a qualitative analysis of the high-dimensional problems by analyzing the low-dimensional models.

In this thesis we demonstrate how to reduce the dimension of a certain class of dynamical systems by construction of k-dimensional submanifolds using the so-called graph transform. The method is suitable for a specific class of problems with spectral gaps, these are often observed. In particular the method is applied to a mechanical system. Furthermore the method has some unique and promising properties compared to other methods.
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.
this work uses operational data from a small Danish supermarket. A three-state model is determined to be most appropriate for describing the dynamics of this system. Advanced local control employing the identified model can contribute to the extension of the control capabilities of the entire supermarket refrigeration system.

**Modelling and Assessment of the Capabilities of a Supermarket Refrigeration System for the Provision of Regulating Power**

This report presents an analysis of the demand response capabilities of a supermarket refrigeration system, with a particular focus on the suitability of this resource for participation in the regulating power market. An ARMAX model of the system is identified from experimental data, and the model is found to have time constants at 10 and 0.12 hours, indicating the potential for the system to provide exibility in both the long- and short-term. Direct- and indirect-control architectures are employed to simulate the demand response attainable from the refrigeration system. A number of complexities are revealed that would complicate the task of devising bids on a conventional power market. These complexities are incurred due to the physical characteristics and constraints of the system as well as the particular characteristics of the control frameworks employed. Simulations considering the provision of up- and down-regulation reveal that allowing the system to occupy any state within its feasible region results in a complex behaviour. This would require intensive monitoring and control and would be excessively complicated to communicate to a market operator. By restricting the operating region of the system this behaviour can be simplified. These restrictions result in a loss of optimality, but a result in a resource that can be communicated to the market operator in the form of a bid containing a quantity of power for up- or down-regulation and the duration for which the service can be provided.
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.
Multijam Solutions in Traffic Models with Velocity-Dependent Driver Strategies

The optimal-velocity follow-the-leader model is augmented with an equation that allows each driver to adjust their target headway according to the velocity difference between the driver and the car in front. In this more detailed model, which is investigated on a ring, stable and unstable multipulse or multijam solutions emerge. Analytical investigations using truncated Fourier analysis are confirmed and complemented by a detailed numerical bifurcation analysis. In addition to standard rotating waves, time-modulated waves are found.

General information
State: Published
Organisations: Department of Physics, Department of Applied Mathematics and Computer Science, Dynamical Systems, Brown University, University of the Basque Country, Bogolyubov Institute for Theoretical Physics
Authors: Carter, P. (Ekstern), Christiansen, P. L. (Intern), Gaididei, Y. B. (Ekstern), Gorria, C. (Ekstern), Sandstede, B. (Ekstern), Sørensen, M. P. (Intern), Starke, J. (Intern)
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Web of Science (2017): Indexed yes
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Scopus rating (2016): SJR 1.046 SNIP 1.311 CiteScore 1.76
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Scopus rating (2013): SJR 0.972 SNIP 1.151 CiteScore 1.61
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.028 SNIP 1.251 CiteScore 1.69
ISI indexed (2012): ISI indexed yes
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Scopus rating (2011): SJR 0.798 SNIP 1.193 CiteScore 1.49
ISI indexed (2011): ISI indexed yes
Negative Differential Resistance due to Nonlinearities in Single and Stacked Josephson Junctions

Josephson junction systems with a negative differential resistance (NDR) play an essential role for applications. As a well-known example, long Josephson junctions of the BSCCO type have been considered as a source of terahertz radiation in recent experiments. Numerical results for the dynamics of the fluxon system have demonstrated that a cavity induced NDR plays a crucial role for the emission of electromagnetic radiation. We consider the case of an NDR region in the McCumber curve itself of a single junction and found that it has an effect on the emission of electromagnetic radiation. Two different shapes of NDR region are considered, and we found that it is essential to distinguish between current bias and voltage bias.
Negative differential resistance in Josephson junctions coupled to a cavity

Regions with negative differential resistance can arise in the IV curve of Josephson junctions and this phenomenon plays an essential role for applications, in particular for THz radiation emission. For the measurement of high frequency radiation from Josephson junctions, a cavity – either internal or external – is often used. A cavity may also induce a negative differential resistance region at the lower side of the resonance frequency. We investigate the dynamics of Josephson junctions with a negative differential resistance in the quasi particle tunnel current, i.e. in the McCumber curve. We find that very complicated and unexpected interactions take place. This may be useful for the interpretation of experimental measurements of THz radiation from intrinsic Josephson junctions.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, University of Sannio
Neutrosophic Logic Applied to Decision Making

Decision making addresses the usage of various methods to select "the best", in some way, alternative strategy (from many available) when a problem is given for solving. The authors propose the usage of neutrosophic way of thinking, called also Smarandache’s logic, to select a model by experts when degrees of trustability, ultrastability (falsehood), and indeterminacy are used to decide. The procedures deal with multi-attribute neutrosophic decision making and a case study on e-learning software objects is presented.

Nonlinear Effects in Examples of Crowd Evacuation Scenarios

Severe accidents with many fatalities have occurred when too many pedestrians had to maneuver in too tight surroundings, as during evacuations of mass events. This demonstrates the importance of a better general understanding of pedestrians and emergent complex behavior in crowds. To this end, we develop both a new microscopic agent-based pedestrian model and also study simplified evacuation scenarios which permit the isolation of relevant nonlinear effects and their systematic investigation. We concentrate on two effects: First, the influence of the position and size of an obstacle in front of an emergency exit on the flux through the exit, and second, the influence of other pedestrians on the route choice of an individual. The first investigation demonstrates the possibility of improving substantially the flow through an exit by placing an obstacle in a suitable way in front of it. The latter shows clearly bistable states and hysteresis effects, indicating the existence of unstable pedestrian flow states in addition to the stable states. Furthermore, this set-up is an example of a radical change of the pedestrian flux by only a small change in the geometry of the evacuation scenario. The results motivate further investigation and eventually engineering use by optimizing the design of large buildings, stations, airports and stadiums for mass events.
Optimal charging of an electric vehicle using a Markov decision process

The combination of electric vehicles and renewable energy is taking shape as a potential driver for a future free of fossil fuels. However, the efficient management of the electric vehicle fleet is not exempt from challenges. It calls for the involvement of all actors directly or indirectly related to the energy and transportation sectors, ranging from governments, automakers and transmission system operators, to the ultimate beneficiary of the change: the end-user. An electric vehicle is primarily to be used to satisfy driving needs, and accordingly charging policies must be designed primarily for this purpose. The charging models presented in the technical literature, however, overlook the stochastic nature of driving patterns. Here we introduce an efficient stochastic dynamic programming model to optimally charge an electric vehicle while accounting for the uncertainty inherent to its use. With this aim in mind, driving patterns are described by an inhomogeneous Markov model that is fitted using data collected from the utilization of an electric vehicle. We show that the randomness intrinsic to driving needs has a substantial impact on the charging strategy to be implemented.
Optimal vaccination strategies against vector-borne diseases

Using a process oriented semi-agent based model, we simulated the spread of Bluetongue virus by Culicoides, biting midges, between cattle in Denmark. We evaluated the minimum vaccination cover and minimum cost for eight different preventive vaccination strategies in Denmark.

The simulation model replicates both a passive and active flight of midges between cattle distributed on pastures and cattle farms in Denmark. A seasonal abundance of midges and temperature dependence of biological processes were included in the model. The eight vaccination strategies were investigated under four different grazing conditions. Furthermore, scenarios were tested with three different index locations stratified for cattle density. The cheapest way to vaccinate cattle with a medium risk profile (less than 1000 total affected cattle) was to vaccinate cattle on pasture. Regional vaccination displayed better results when index cases were in the vaccinated areas. However, given that the long-range spread of midge borne disease is still poorly quantified, more robust national vaccination schemes seem preferable.
Predicting Plasma Glucose From Interstitial Glucose Observations Using Bayesian Methods

One way of constructing a control algorithm for an artificial pancreas is to identify a model capable of predicting plasma glucose (PG) from interstitial glucose (IG) observations. Stochastic differential equations (SDEs) make it possible to account both for the unknown influence of the continuous glucose monitor (CGM) and for unknown physiological influences. Combined with prior knowledge about the measurement devices, this approach can be used to obtain a robust predictive model. A stochastic-differential-equation-based gray box (SDE-GB) model is formulated on the basis of an identifiable physiological model of the glucoregulatory system for type 1 diabetes mellitus (T1DM) patients. A Bayesian method is used to estimate robust parameters from clinical data. The models are then used to predict PG from IG observations from 2 separate study occasions on the same patient. First, all statistically significant diffusion terms of the model are identified using likelihood ratio tests, yielding inclusion of \( \sigma_{\text{Isc}} \), \( \sigma_{\text{Gp}} \), and \( \sigma_{\text{Gsc}} \). Second, estimates using maximum likelihood are obtained, but prediction capability is poor. Finally a Bayesian method is implemented. Using this method the identified models are able to predict PG using only IG observations. These predictions are assessed visually. We are also able to validate these estimates on a separate data set from the same patient. This study shows that SDE-
GBs and a Bayesian method can be used to identify a reliable model for prediction of PG using IG observations obtained with a CGM. The model could eventually be used in an artificial pancreas.

**General information**

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**Predictive densities for day-ahead electricity prices using time-adaptive quantile regression**

A large part of the decision-making problems actors of the power system are facing on a daily basis requires scenarios for day-ahead electricity market prices. These scenarios are most likely to be generated based on marginal predictive densities for such prices, then enhanced with a temporal dependence structure. A semi-parametric methodology for generating such densities is presented: it includes: (i) a time-adaptive quantile regression model for the 5%–95% quantiles; and (ii) a description of the distribution tails with exponential distributions. The forecasting skill of the proposed model is compared to that of four benchmark approaches and the well-known the generalist autoregressive conditional
heteroskedasticity (GARCH) model over a three-year evaluation period. While all benchmarks are outperformed in terms of forecasting skill overall, the superiority of the semi-parametric model over the GARCH model lies in the former’s ability to generate reliable quantile estimates.

**General information**

State: Published

Organisations: Department of Applied Mathematics and Computer Science, Department of Electrical Engineering, Center for Electric Power and Energy, Dynamical Systems, ENFOR A/S

Authors: Jónsson, T. (Intern), Pinson, P. (Intern), Madsen, H. (Intern), Nielsen, H. A. (Ekstern)

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**Predictive Food Microbiology: new tools for risk assessment and dairy product development**

Listeria monocytogenes is a well-known food borne pathogen that potentially causes listeriosis. No outbreaks or cases of listeriosis have been associated with cottage cheese, but several confirmed cases and outbreaks in the EU and the US have been related to dairy products made from raw or pasteurised milk. This, in combination with the fact that cottage cheese support growth of Listeria monocytogenes, induces a documentation requirement on the food producer. In the EU
regulatory framework, mathematical models are recognised as a suitable supplement to traditional microbiological methods. The models can be used for documentation of compliance with microbiological criteria for Listeria monocytogenes under reasonably foreseeable conditions. Cottage cheese is a fresh, fermented dairy product. It consists of a fermented cheese curd mixed with a fresh or cultured cream dressing. The product contains considerable concentrations of lactic acid bacteria from the added starter or aroma cultures. The presence of these microorganisms induces some complexity to the product, since the lactic acid bacteria metabolites and e.g. bacteriocins exhibit an inhibitory effect towards co-culture microorganisms such as Listeria monocytogenes. During storage at temperatures allowing the mesophilic lactic acid bacteria to grow (> 8-10°C), a pronounced inter-bacterial interaction and growth inhibition of co-culture Listeria monocytogenes was observed. These observations emphasised the need for inter-bacterial interaction models when predicting the growth response of Listeria monocytogenes in fermented dairy products. The objective of the PhD-project was to develop new, or extend existing mathematical models to be used for risk assessment and product development. When the project was initiated, none of the existing predictive models were found to appropriately describe the simultaneous growth of lactic acid bacteria from the added starter or aroma culture and Listeria monocytogenes in cottage cheese. New, deterministic growth models were developed for Listeria monocytogenes, starter lactic acid bacteria and aroma lactic acid bacteria. The new cardinal parameter type growth models included the effect of temperature, pH, NaCl, lactic and sorbic acid. The models were developed based on growth data obtained from absorbance measurements in liquid laboratory media and growth data obtained in cottage cheese with fresh or cultured cream dressing. An important step in the modelling procedure was the calibration of the reference growth rate ($\mu_{ref}$, h-1 at 25°C) which was strongly affected by the dominating lactic acid bacteria culture. By combining the developed secondary growth models with the empirical Jameson approach, good predictions of the simultaneous growth of Listeria monocytogenes and lactic acid bacteria were obtained. Both growth rate and maximum population densities of Listeria monocytogenes was accurately described under constant and dynamic storage temperatures (between 5°C and 15°C). The inter-bacterial interaction was clearly important to include when predicting growth response of Listeria monocytogenes in fermented dairy products. Alternative, semi-mechanistic, imodelling approaches were evaluated based on methods applied in the fermentation technology. The dynamics of lactic acid concentration and product pH was related to growth of lactic acid bacteria by the yield factor concept. The ability to predict the maximum population density of Listeria monocytogenes in cottage cheese based on dynamic lactic acid and pH was evaluated. For cottage cheese with fresh cream dressing, the semi-mechanistic interaction model successfully predicted the maximum population density. Lactic acid and pH was, however, insufficient to describe the growth inhibition of Listeria monocytogenes observed in cottage cheese with cultured cream dressing. Improved, mechanistic, prediction of Listeria monocytogenes in cottage cheese with cultured cream dressing would require that additional mechanisms were included in the model, such as other metabolites or bacteriocins. Finally, the semi-mechanistic and the empirical Jameson approach to inter-bacterial interaction modelling were compared. The empirical Jameson model consistently performed equally well or better than the more complex semi-mechanistic model. In order to evaluate the growth response of more realistic concentrations of Listeria monocytogenes and to take variability into account, a stochastic approach was applied. The deterministic growth models were used in combination with stochastic input values for bacterial concentration; lag time duration and product characteristics. Good agreement between predicted and observed growth was obtained, when applying broth based lag time distributions for Listeria monocytogenes single cells in combination with the relative lag time concept. Furthermore, application of relative lag time distributions from Listeria monocytogenes population data provided good predictions of the growth response of only a few Listeria monocytogenes cells in cottage cheese at chilled temperatures. From the results of the present PhD-project it was found that once solid, deterministic, secondary growth models have been developed and validated, they can be modified and/or extended to a range of other modelling procedures. Furthermore, inclusion of inter-bacterial interaction was considered to be an inevitable part when modelling and predicting growth of L. monocytogenes in fermented dairy products. In general, simple approaches to describe interaction and growth inhibition (empirical approach), lag time prediction of individual cells (variability in population RLT-values) and representation of e.g. variable product characteristics (bootstrapping from empirical distributions) were advocated. It is believed that it is necessary to define some applicable methodologies for the development of growth models for complex products such as fermented dairy products. Model development is a comprehensive process with an almost infinite data requirement and the findings of the present PhD-project is thought to be important in relation to the development of predictive models that are valuable for, and readily applicable in the food industry.

**General information**

State: Published
Organisations: National Food Institute, Division of Industrial Food Research, Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Østergaard, N. B. (Intern), Dalgaard, P. (Intern), Christiansen, L. E. (Intern)
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Probabilistic Forecasting for On-line Operation of Urban Drainage Systems
This thesis deals with the generation of probabilistic forecasts in urban hydrology. In particular, we focus on the case of runoff forecasting for real-time control (RTC) on horizons of up to two hours.

For the generation of probabilistic on-line runoff forecasts, we apply the stochastic grey-box model approach. Building on previous work concerning the development of conceptual stochastic rainfall-runoff model structures, we
- investigate approaches for the calibration of model parameters that tune the models for multistep predictions,
- develop an approach for generating probabilistic multistep predictions of runoff volume in an on-line setting,
- develop a new approach for dynamically modelling runoff forecast uncertainty.

We investigate how rainfall inputs can be optimally combined for runoff forecasting with stochastic grey-box models and what effect different types of radar rainfall measurements and forecasts have on on-line runoff forecast quality.

Finally, we implement the stochastic grey-box model approach in a real-world real-time control (RTC) setup and study how RTC can benefit from a dynamic quantification of runoff forecast uncertainty.

Probabilistic Forecasts of Solar Irradiance by Stochastic Differential Equations
Probabilistic forecasts of renewable energy production provide users with valuable information about the uncertainty associated with the expected generation. Current state-of-the-art forecasts for solar irradiance have focused on producing reliable point forecasts. The additional information included in probabilistic forecasts may be paramount for decision makers to efficiently make use of this uncertain and variable generation. In this paper, a stochastic differential equation framework for modeling the uncertainty associated with the solar irradiance point forecast is proposed. This modeling approach allows for characterizing both the interdependence structure of prediction errors of short-term solar irradiance and their predictive distribution. Three different stochastic differential equation models are first fitted to a training data set and subsequently evaluated on a one-year test set. The final model proposed is defined on a bounded and time-varying state space with zero probability almost surely of events outside this space.
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Proportional forecasts of wind power generation accounting for geographically dispersed information
Forecasts of wind power generation are a necessary input to decision-making problems for reliable and economic power systems operations in a smart grid context. Thanks to the wealth of spatially distributed data, also of high temporal resolution, such forecasts may be optimized by accounting for spatio-temporal effects that are so far merely considered. The way these effects may be included in
relevant models is described for the case of both parametric and nonparametric approaches to generating probabilistic forecasts. The resulting predictions are evaluated on the real-world test case of a large offshore wind farm in Denmark (Nysted, 165 MW), where a portfolio of 19 other wind farms is seen as a set of geographically distributed sensors, for lead times between 15 minutes and 8 hours. Forecast improvements are shown to mainly come from the spatio-temporal correction of the first order moments of predictive densities. The best performing approach, based on adaptive quantile regression, using spatially corrected point forecasts as input, consistently outperforms the state-of-the-art benchmark based on local information only, by 1.5%-4.6%, depending upon the lead time.

**General information**

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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Electrical Engineering, Center for Electric Power and Energy
Authors: Tastu, J. (Intern), Pinson, P. (Intern), Trombe, P. (Intern), Madsen, H. (Intern)
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**Renewable energy, Prediction, Decision-Making, Power systems operations, Offshore**

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**Probabilistic modelling in urban drainage – two approaches that explicitly account for temporal variation of model errors**

This article presents and compares two approaches that consider temporal variations of model errors during stochastic modelling and uncertainty analysis. Time-dynamic error variations should be considered especially in urban drainage modelling because of model structure deficits and the sources of input uncertainties observed in the models. The explicit
inclusion of such variations in the modelling process will lead to a better fulfilment of the assumptions made in formal statistical frameworks, thus reducing the need to resolve to informal methods. The two approaches presented here are the external bias description (EBD) and the internal noise description (IND, also known as stochastic grey-box model). The former approach can add a bias with time-varying mean and variance to the output of any model, while the latter approach uses stochastic model equations and continuously updates the model to observations. After a brief discussion of the assumptions made for likelihood-based parameter inference, we illustrated the basic principles of both approaches on the example of sewer flow modelling with a conceptual rainfallrunoff model. The results from a real-world case study suggested that both approaches can yield reliable simulations and forecasts. The EBD approach had performed stronger in simulation but was computationally more expensive while the IND approach was suitable for online applications.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Department of Environmental Engineering, Urban Water Engineering, Dynamical Systems, Swiss Federal Institute of Technology, Swiss Federal Institute of Aquatic Science and Technology
Authors: Löwe, R. (Intern), Del Giudice, D. (Ekstern), Mikkelsen, P. S. (Intern), Rieckermann, J. (Ekstern), Madsen, H. (Intern)
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Probabilistic online runoff forecasting for urban catchments using inputs from rain gauges as well as statically and dynamically adjusted weather radar
We investigate the application of rainfall observations and forecasts from rain gauges and weather radar as input to operational urban runoff forecasting models. We apply lumped rainfall runoff models implemented in a stochastic grey-box modelling framework. Different model structures are considered that account for the spatial distribution of rainfall in different degrees of detail.

Considering two urban example catchments, we show that statically adjusted radar rainfall input improves the quality of probabilistic runoff forecasts as compared to input based on rain gauge observations, although the characteristics of these radar measurements are rather different from those on the ground. Data driven runoff forecasting models can to some extent adapt to bias of the rainfall input by model parameter calibration and state-updating. More detailed structures in these models provide improved runoff forecasts compared to the structures considering mean areal rainfall only.

A time-dynamic adjustment of the radar data to rain gauge data provides improved rainfall forecasts when compared with rainfall observations on the ground. However, dynamic adjustment reduces the potential for creating runoff forecasts and in fact also leads to reduced cross correlation between radar rainfall and runoff measurements. We conclude that evaluating the performance of radar rainfall adjustment against rain gauges may not always be adequate and that adjustment procedure and online runoff forecasting should ideally be considered as one unit.

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Redefining the merit order of stochastic generation in forward markets.

This letter proposes a new merit order for the dispatch of stochastic production in forward markets (e.g., dayahead markets). The proposed merit order considers not only the marginal cost of the stochastic generating unit, which is often
very low or zero, but also the projected cost of balancing its energy deviations during the real-time operation of the power
system. We show, through an illustrative example, that the proposed merit order leads to increased market efficiency as
the penetration of stochastic generation in the electricity market grows.

**General information**

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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Electrical
Engineering, Center for Electric Power and Energy, University of Copenhagen

Authors: Morales González, J. M. (Intern), Zugno, M. (Intern), Pineda Morente, S. (Ekstern), Pinson, P. (Intern)

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Scopus rating (2006): SJR 1.233 SNIP 2.316

Web of Science (2006): Indexed yes
Regulating Power from Supermarket Refrigeration

This paper presents an analysis of the demand response capabilities of a supermarket refrigeration system, with a particular focus on the suitability for participation in the regulating power market. An ARMAX model of a supermarket refrigeration system is identified using experimental data from the Danfoss refrigeration test centre. The complexities of modelling demand response are demonstrated through simulation. Simulations are conducted by placing the identified model in a direct-control demand response architecture, with power reference tracking using model predictive control. The energylimited nature of demand response from refrigeration is identified as the key consideration when considering participation in the regulating power market. It is demonstrated that by restricting the operating regions of the supermarket refrigeration system, a simple relationship can be found between the available up- or down-regulation power, and the duration for which the service can be sustained. The available demand response resource within these operational restrictions is reduced from the optimised physical capabilities. The benefit of these restrictions is that the available demand response can be represented in a manner that is sufficiently simple to communicate to a market operator in the form of a bid for the provision of regulating power.

Relative Lyapunov Center Bifurcations

Relative equilibria (REs) and relative periodic orbits (RPOs) are ubiquitous in symmetric Hamiltonian systems and occur, for example, in celestial mechanics, molecular dynamics, and rigid body motion. REs are equilibria, and RPOs are periodic orbits of the symmetry reduced system. Relative Lyapunov center bifurcations are bifurcations of RPOs from REs corresponding to Lyapunov center bifurcations of the symmetry reduced dynamics. In this paper we first prove a relative Lyapunov center theorem by combining recent results on the persistence of RPOs in Hamiltonian systems with a symmetric Lyapunov center theorem of Montaldi, Roberts, and Stewart. We then develop numerical methods for the detection of relative Lyapunov center bifurcations along branches of RPOs and for their computation. We apply our methods to Lagrangian REs of the $N$-body problem.
Reliability in the Power System Modeled in a Multi-Stage Stochastic Mixed Integer Programming Model

Contributions from this article are that it takes the characteristics of the power system into account at different stages, which gives a more realistic presentation of the welfare aspects to be gained by an optimal operation/dispatch of the power system. This article is utilizing a Multi-Stage Stochastic Mixed Integer Programming Model that handles uncertainty in a flexible and practical way. The method applied relies on state-of-the-art modeling within this field, but the method applied in this article is extended by using decomposition.
Retrospective community based explorative study on Cisplatin-based adjuvant chemotherapy vs. surgery only in completely resected stage IB non-small cell lung cancer (NSCLC)

Risk-Based Model Predictive Control of Urban Drainage Networks: When Uncertainty matters

Setting up and validating a complex model for a simple homogeneous wall

The present paper describes modelling of the thermal dynamics of a real wall tested in dynamic outdoor weather conditions, to identify all the parameters needed for its characterisation. Specifically, the U value, absorptance and effective heat capacity are estimated for the wall using grey-box modelling based on statistical methods and known physical dynamic energy balance equations, related to the heat flux density through a simple and homogeneous wall. The experimental test was carried out in a hot-temperature climate for nine months. This study aims at proposing a dynamic method improving the regression averages method for estimation of parameters which describe the thermal behaviour of the wall. Solar irradiance and long-wave radiation balance terms are added in the heat balance equation besides modelling of wind speed effect to achieve a complete description of the relevant phenomena which affect the thermal dynamics of the wall. The method is applied using different frequency data samples looking for the best to study this wall. The U value obtained characterising the wall is consistent with the one given by the regression averages method.
Stochastic rainfall-runoff forecasting: parameter estimation, multi-step prediction, and evaluation of overflow risk

Probabilistic runoff forecasts generated by stochastic greybox models can be notably useful for the improvement of the decision-making process in real-time control setups for urban drainage systems because the prediction risk relationships in these systems are often highly nonlinear. To date, research has primarily focused on one-step-ahead flow predictions for identifying, estimating, and evaluating greybox models. For control purposes, however, stochastic predictions are required for longer forecast horizons and for the prediction of runoff volumes, rather than flows. This article therefore analyzes the quality of multistep ahead forecasts of runoff volume and considers new estimation methods based on scoring rules for k-step-ahead predictions. The study shows that the score-based methods are, in principle, suitable for the estimation of model parameters and can therefore help the identification of models for cases with noisy in-sewer observations. For the prediction of the overflow risk, no improvement was demonstrated through the application of stochastic forecasts instead of point predictions, although this result is thought to be caused by the notably simplified setup used in this analysis. In conclusion, further research must focus on the development of model structures that allow the proper separation of dry and wet weather uncertainties and simulate runoff uncertainties depending on the rainfall input.
Recently, highly resolved experiments and simulations have provided detailed insight into the dynamics of turbulent pipe flow. This has revived the interest in identifying mechanisms that generate chaotic transients with superexponential growth of lifetime as a function of a control parameter, the Reynolds number for pipe flow, and with transitions from bounded chaotic patches to an invasion of space of irregular motion. Dynamical systems models are unique tools in this respect because they can provide insight into the origin of the very long lifetime of puffs, and the dynamical mechanism leading to the transition from puffs to slugs in pipe flow. The present paper contributes to this enterprise by introducing a unidirectionally coupled map lattice. It mimics three of the salient features of pipe-flow turbulence: (i) the transition from laminar flow to puffs, (ii) a superexponential scaling of puff lifetime, and (iii) the transition from puffs to slugs by an unbinding transition in an intermittency scenario. In our model all transitions and scalings are theoretically described from a dynamical systems point of view.
Waste Water Treatment Plants and the Smart Grid

Denmark’s political ambitions of a fossil fuel free energy system by 2050 calls for more renewable energy sources such as wind and solar. These green energy resources fluctuate and the transition to a green energy system requires a Smart Grid with flexible consumers that balance the fluctuating power production. The energy-heavy processes for waste water transport and treatment could potentially provide a flexible operation with storage capabilities and be a valuable asset to a Smart Grid. In order to enable Waste Water Treatment Plants (WWTPs) as flexible prosumers in the future Smart Grid, we must update their process control system to model based predictive control that monitors the changed flexible operation and plans ahead. The primary aim of a WWTP is to treat the incoming waste water as much as possible to ensure a sufficient effluent water quality and protect the environment of the recipient. The secondary aim is to treat the waste water using as little energy as possible. In the future waste water will be considered an energy resource, that contains valuable nutrients convertible to green biogas and in turn electricity and heat. In a Smart Grid consuming or producing energy at the right time is key to both lower plant electricity costs and actively help to balance the energy system. Predictions of the WWTP and sewer system operation could help a model based controller to adapt power consumption and production according to the energy system flexibility needs; incentivized through energy markets and prices. We are in the process of upgrading the current control system to prepare a flexible operation and Smart Grid market integration. The prototype...
system will be tested online at a plant in Denmark, that in the current market could save up to 300.000 DKK/year in electricity costs. The solution is based on existing available online plant sensors and is expected to be part of Krüger's advanced process control software STAR control® already used at plants worldwide.

**General information**

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Krüger A/S
Authors: Halvgaard, R. (Intern), Tychsen, P. (Ekstern), Munk-Nielsen, T. (Ekstern), Grum, M. (Ekstern), Madsen, H. (Intern)
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Main Research Area: Technical/natural sciences
Conference: DTU Sustain Conference 2014, Lyngby, Denmark, 17/12/2014 - 17/12/2014
Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2014

**Weather radars – the new eyes for offshore wind farms?**

Offshore wind fluctuations are such that dedicated prediction and control systems are needed for optimizing the management of wind farms in real-time. In this paper, we present a pioneer experiment – Radar@Sea – in which weather radars are used for monitoring the weather at the Horns Rev offshore wind farm, in the North Sea. First, they enable the collection of meteorological observations at high spatio-temporal resolutions for enhancing the understanding of meteorological phenomena that drive wind fluctuations. And second, with the extended visibility they offer, they can provide relevant inputs to prediction systems for anticipating changes in the wind fluctuation dynamics, generating improved wind power forecasts and developing specific control strategies. However, integrating weather radar observations into automated decision support systems is not a plug-and-play task, and it is important to develop a multi-disciplinary approach linking meteorology and statistics. Here, (i) we describe the settings of the Radar@Sea experiment, (ii) we report the experience gained with these new remote sensing tools, (iii) we illustrate their capabilities with some concrete meteorological events observed at Horns Rev and (iv) we discuss the future perspectives for weather radars in wind energy. Copyright © 2013 John Wiley & Sons, Ltd.

**General information**

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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Electrical Engineering, Center for Electric Power and Energy, Department of Wind Energy, Meteorology, Wind Energy Systems, Danish Meteorological Institute, DHI Denmark, DONG Energy A/S, Vattenfall A/S
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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.196 SNIP 2.086 CiteScore 3.06
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Wind resource assessment and wind power forecasting

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Editors: Hvidtfeldt Larsen, H., Sønderberg Petersen, L.
ISBN (Print): 978-87-550-3969-8
Main Research Area: Technical/natural sciences
Electronic versions:
DTU_INTL_ENERGY_REP_2014_WIND_79_85.pdf
Publication: Research - peer-review › Book chapter – Annual report year: 2014

Wind Speed Estimation and Parametrization 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.

General information
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Organisations: Department of Wind Energy, Wind Energy Systems, Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Göçmen Bozkurt, T. (Intern), Giebel, G. (Intern), Poulsen, N. K. (Intern), Mirzaei, M. (Intern)
Number of pages: 1
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Main Research Area: Technical/natural sciences
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Wind_Speed_Estimation_poster.pdf
Links:
http://www.ewea.org/annual2014/conference/
Publication: Research - peer-review › Poster – Annual report year: 2014

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.

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Organisations: Department of Wind Energy, Wind Energy Systems, Department of Applied Mathematics and Computer
Science, Dynamical Systems
Authors: Göçmen Bozkurt, T. (Intern), Giebel, G. (Intern), Poulsen, N. K. (Intern), Mirzaei, M. (Intern)
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Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.253 SNIP 0.344 CiteScore 0.32
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
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BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.28 SNIP 0.354 CiteScore 0.33
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Scopus rating (2011): SJR 0.292 SNIP 0.352 CiteScore 0.43
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Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
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Scopus rating (2008): SJR 0.265 SNIP 0.294
Web of Science (2008): Indexed yes
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Abelpris til Pierre Deligne for banebrydende matematisk rapsodi om de algebraiske ligningers geometri

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State: Published
Organisations: Department of Applied Mathematics and Computer Science, Cognitive Systems, Dynamical Systems
Authors: Hansen, V. L. (Intern), Hjorth, P. G. (Intern)
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Publication date: 2013
Main Research Area: Technical/natural sciences

A bilevel model for electricity retailers' participation in a demand response market environment
Demand response programmes are seen as one of the contributing solutions to the challenges posed to power systems by the large-scale integration of renewable power sources, mostly due to their intermittent and stochastic nature. Among demand response programmes, real-time pricing schemes for small consumers are believed to have significant potential for peak-shaving and load-shifting, thus relieving the power system while reducing costs and risk for energy retailers. This paper proposes a game theoretical model accounting for the Stackelberg relationship between retailers (leaders) and consumers (followers) in a dynamic price environment. Both players in the game solve an economic optimisation problem subject to stochasticity in prices, weather-related variables and must-serve load. The model allows the determination of the dynamic price-signal delivering maximum retailer profit, and the optimal load pattern for consumers under this pricing. The bilevel programme is reformulated as a single-level MILP, which can be solved using commercial off-the-shelf optimisation software. In an illustrative example, we simulate and compare the dynamic pricing scheme with fixed and time-of-use pricing. We find that the dynamic pricing scheme is the most effective in achieving load-shifting, thus reducing retailer costs for energy procurement and regulation in the wholesale market. Additionally, the redistribution of the saved costs between retailers and consumers is investigated, showing that real-time pricing is less convenient than fixed and time-of-use price for consumers. This implies that careful design of the retail market is needed. Finally, we carry out a sensitivity analysis to analyse the effect of different levels of consumer flexibility.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Zugno, M. (Intern), Morales González, J. M. (Intern), Pinson, P. (Intern), Madsen, H. (Intern)
Pages: 182-197
Publication date: 2013
Main Research Area: Technical/natural sciences
A Coordination Scheme for Distributed Model Predictive Control: Integration of Flexible DERs

This paper presents a control scheme based on distributed model predictive control (DMPC) for coordinating flexible distributed energy resources (DER) of heterogeneous type in the Smart Grid with minimum system integration effort. This approach can be used for reducing the peak power exchange between the grid and a cluster of units in the same feeder in price-driven demand response applications. Preliminary simulations prove that the proposed coordination scheme for DMPC succeeds in coordinating flexible DER unit, achieving significant peak shaving when required. The rationale of this approach consists in coordinating independent units equipped with local MPC controller via simple information passing.
and hiding in the local controllers the units' dynamics.

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**Adaptive Trailing Edge Flaps for Active Load Alleviation in a Smart Rotor Configuration**
The work investigates the development of an active smart rotor concept from an aero-servo-elastic perspective. An active smart rotor is a wind turbine rotor that, through a combination of sensors, control units and actuators, is able to alleviate the fluctuating part of the aerodynamic loads it has to withstand. The investigation focuses on a specific actuator type: the Adaptive Trailing Edge Flap (ATEF), which introduces a continuous deformation of the aft part of the airfoil camber-line. An aerodynamic model that accounts for the steady and unsteady effects of the flap deflection on a 2D airfoil section is developed, and, considering both attached and separated flow conditions, is validated by comparison against Computational Fluid Dynamic solutions and a panel code method. The aerodynamic model is integrated in the BEM-based aerelastic simulation code HAWC2, thus providing a tool able to simulate the response of a wind turbine equipped with ATEF.

A load analysis of the NREL 5 MW reference turbine in its baseline configuration reveals that the highest contribution to the blade flapwise fatigue damage originates from normal operation above rated wind speed, and from loads characterized by frequencies below 1 Hz. The analysis also reports that periodic load variations on the turbine blade account for nearly 11 % of the blade flapwise lifetime fatigue damage, while the rest is ascribed to load variations from disturbances of stochastic nature.

The study proposes a smart rotor configuration with flaps laid out on the outer 20 % of the blade span, from 77 % to 97% of the blade length. The configuration is first tested with a simplified cyclic control approach, which gives a preliminary indication of the load alleviation potential, and also reveals the possibility to enhance the rotor energy capture below rated conditions by using the flaps.

Two model based control algorithms are developed to actively alleviate the fatigue loads on the smart rotor with ATEF. The first algorithm features a linear quadratic regulator with periodic disturbance rejection, and controls the deflection of the flap on each blade based on measurements of the root flapwise bending moment; each blade is considered as an independent Single Input-Single Output system. The second algorithm is a Multiple Input-Multiple Output Model Predictive Control (MIMO-MPC), which monitors the whole turbine response, and controls all the available actuators: ATEF, individual blade pitch, and generator. Both algorithms include frequency-dependent weighting of the control actions in order to limit high frequency control activity, and thus effectively reduce actuators use and wear.

The smart rotor performances are evaluated from HAWC2 simulations reproducing the response to standard turbulent wind fields. Both algorithms reduce the lifetime fatigue damage on the blade root flapwise bending moment by 15 % using the ATEF actuators. Whereas, by combining pitch and flap actions, the MIMO-MPC reports alleviation results close to 30 %. The MIMO-MPC requires lower flap activity, and also achieves higher reductions of the tower fatigue loads, thus indicating that a combined control approach that coordinates and integrates all available sensors and actuators has the potential for overall better results than achieved by a series of independent control systems.
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

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
Authors: Petersen, L. N. (Intern), Poulsen, N. K. (Intern), Niemann, H. H. (Intern), Utzen, C. (Ekstern), Jørgensen, J. B. (Intern)
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Source-ID: u::10297
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An arctic low-energy house as experimental setup for studies of heat dynamics of buildings

This paper addresses the difficulties in pinpointing reasons for unexpectedly high energy consumption in construction, and in low-energy houses especially. Statistical methods are applied to improve the insight into the energy performance and heat dynamics of a building based on consumption records and weather data. Dynamical methods separate influences from outdoor temperature, solar radiation, and wind on the energy consumption in the building. The studied building is a low-energy house in Sisimiut, Greenland. Weather conditions like large temperature differences between indoors and outdoors throughout long winters, strong winds, and very different circumstances regarding solar radiation compared to areas where low-energy houses are usually built, make the location very interesting for modeling and testing purposes. In 2011 new measurement equipment was installed in the house, which will be used to develop more detailed models of the heat dynamics and energy performance in relation to different meteorological variables, heating systems, and user behavior. This type of models is known as a graybox model and is been introduced in this paper.

General information

State: Published
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
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Electrical Engineering, Automation and Control, Aalborg University
Authors: Mirzaei, M. (Intern), Soltani, M. (Ekstern), Poulsen, N. K. (Intern), Niemann, H. H. (Intern)
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Source-ID: u::7467
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A non-parametric method for correction of global radiation observations
This paper presents a method for correction and alignment of global radiation observations based on information obtained from calculated global radiation, in the present study one-hour forecast of global radiation from a numerical weather prediction (NWP) model is used. Systematical errors detected in the observations are corrected. These are errors such as: tilt in the leveling of the sensor, shadowing from surrounding objects, clipping and saturation in the signal processing, and errors from dirt and wear. The method is based on a statistical non-parametric clear-sky model which is applied to both the observed and the calculated radiation in order to find systematic deviations between them. The method is applied to correct global radiation observations from a climate station located at a district heating plant in Denmark. The results are compared to observations recorded at the Danish Technical University. The method can be useful for optimized use of solar radiation observations for forecasting, monitoring, and modeling of energy production and load which are affected by solar radiation.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Civil Engineering, Section for Building Physics and Services
Authors: Bacher, P. (Intern), Madsen, H. (Intern), Perers, B. (Intern), Nielsen, H. A. (Intern)
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BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 4.52 SJR 1.547 SNIP 1.748
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BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.974 SNIP 2.143 CiteScore 4.61
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.014 SNIP 2.704 CiteScore 4.77
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.058 SNIP 2.92 CiteScore 4.44
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
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Scopus rating (2012): SJR 1.655 SNIP 2.55 CiteScore 3.65
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.326 SNIP 2.223 CiteScore 3.19
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.419 SNIP 2.161
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.301 SNIP 2.158
Web of Science (2009): Indexed yes
A Robust Optimization Approach to Energy and Reserve Dispatch in Electricity Markets

To a large extent, electricity markets worldwide still rely on deterministic procedures for clearing energy and reserve auctions. However, larger and larger shares of the production mix consist of renewable sources whose nature is stochastic and non-dispatchable, as their output is not known with certainty and cannot be controlled by the operators of the production units. Stochastic programming models for the joint determination of the day-ahead energy and reserve dispatch, necessary for coping with the real-time output deviations from these sources, have been proposed in the literature. In this work, we take an alternative approach and cast the problem as an adaptive robust optimization problem. The day-ahead and reserve schedules determined in this fashion yield the minimum system cost, accounting for the cost of the redispatching decisions at the balancing stage, in the worst-case realization of the stochastic production within a specified uncertainty set. In a case-study based on a 24-node system, we assess the degree of suboptimality of the robust solution with respect to the optimal dispatch obtained with a stochastic programming approach, and compare their worst-case cost. Furthermore, we discuss the robustness of these two alternative approaches with respect to changes in the distribution of the uncertainty, as well as their computational properties.
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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Organisations: Department of Wind Energy, Aeroelastic Design, Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Henriksen, L. C. (Intern), Hansen, M. H. (Intern), Poulsen, N. K. (Intern)
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Web of Science (2017): Indexed yes
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Scopus rating (2016): CiteScore 3.37 SJR 1.104 SNIP 2.306
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.196 SNIP 2.086 CiteScore 3.06
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.272 SNIP 3.75 CiteScore 3.42
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.275 SNIP 2.464 CiteScore 2.75
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.126 SNIP 2.39 CiteScore 2.36
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Calculation of alternating current losses in stacks and coils made of second generation high temperature superconducting
tapes for large scale applications

A homogenization method to model a stack of second generation High Temperature Superconducting tapes under AC
applied transport current or magnetic field has been obtained. The idea is to find an anisotropic bulk equivalent for the
stack such that the geometrical layout of the internal alternating structures of insulating, metallic, superconducting, and
substrate layers is “washed” out while keeping the overall electromagnetic behavior of the original stack. We disregard
assumptions upon the shape of the critical region and use a power law E-J relationship allowing for overcritical current
densities to be considered. The method presented here allows for a computational speedup factor of up to 2 orders of
magnitude when compared to full 2-D simulations taking into account the actual dimensions of the stacks without
compromising accuracy.

General information
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Organisations: Department of Wind Energy, Wind Energy Systems, Department of Electrical Engineering, Center for
Electric Power and Energy, Department of Applied Mathematics and Computer Science, Dynamical Systems, Karlsruhe
Institute of Technology KIT
Authors: Zermeno, V. M. R. (Ekstern), Abrahamsen, A. B. (Intern), Mijatovic, N. (Intern), Jensen, B. B. (Intern), Sørensen,
M. P. (Intern)
Number of pages: 9
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Web of Science (2017): Indexed yes
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Scopus rating (2016): CiteScore 1.72 SJR 0.632 SNIP 0.815
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.618 SNIP 0.84 CiteScore 1.57
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.005 SNIP 1.18 CiteScore 2.04
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.165 SNIP 1.317 CiteScore 2.24
ISI indexed (2013): ISI indexed yes
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BFI (2011): BFI-level 1
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Web of Science (2011): Indexed yes
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Scopus rating (2010): SJR 1.47 SNIP 1.195
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.518 SNIP 1.238
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
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Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.708 SNIP 1.395
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.947 SNIP 1.649
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 2.034 SNIP 1.627
Web of Science (2005): Indexed yes
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Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 2.019 SNIP 1.525
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 2.225 SNIP 1.674
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 2.079 SNIP 1.554
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 2.338 SNIP 1.543
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 2.071 SNIP 1.517
Chance-constrained optimization of demand response to price signals
Household-based demand response is expected to play an increasing role in supporting the large scale integration of renewable energy generation in existing power systems and electricity markets. While the direct control of the consumption level of households is envisaged as a possibility, a credible alternative is that of indirect control based on price signals to be sent to these end-consumers. A methodology is described here allowing to estimate in advance the potential response of flexible end-consumers to price variations, subsequently embedded in an optimal price-signal generator. In contrast to some real-time pricing proposals in the literature, here prices are estimated and broadcast once a day for the following one, for households to optimally schedule their consumption. The price-response is modeled using stochastic finite impulse response (FIR) models. Parameters are estimated within a recursive least squares (RLS) framework using data measurable at the grid level, in an adaptive fashion. Optimal price signals are generated by embedding the FIR models within a chance-constrained optimization framework. The objective is to keep the price signal as unchanged as possible from the reference market price, whilst keeping consumption below a pre-defined acceptable level

General information
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Organisations: Department of Applied Mathematics and Computer Science, Department of Electrical Engineering, Center for Electric Power and Energy, Dynamical Systems
Authors: Dorini, G. F. (Intern), Pinson, P. (Intern), Madsen, H. (Intern)
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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 3.785 SNIP 3.424 CiteScore 8.48
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 3.105 SNIP 3.799 CiteScore 7.77
Web of Science (2014): Indexed yes
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Scopus rating (2013): SJR 3.175 SNIP 4.831 CiteScore 9.88
ISI indexed (2013): ISI indexed no
Web of Science (2013): Indexed yes
Scopus rating (2012): SJR 2.023 SNIP 6.821 CiteScore 13.33
ISI indexed (2012): ISI indexed no
Web of Science (2012): Indexed yes
Scopus rating (2011): SJR 0.902 SNIP 6.022 CiteScore 11.78
ISI indexed (2011): ISI indexed no
Web of Science (2011): Indexed yes
Comparing control strategies against foot-and-mouth disease: Will vaccination be cost-effective in Denmark?

Recent outbreaks of foot-and-mouth disease (FMD) in Europe have highlighted the need for assessment of control strategies to optimise control of the spread of FMD. Our objectives were to assess the epidemiological and financial impact of simulated FMD outbreaks in Denmark and the effect of using ring depopulation or emergency vaccination to control these outbreaks. Two stochastic simulation models (InterSpreadPlus (ISP) and the modified Davis Animal Disease Simulation model (DTU-DADS)) were used to simulate the spread of FMD in Denmark using different control strategies. Each epidemic was initiated in one herd (index herd), and a total of 5000 index herds were used. Four types of control measures were investigated: (1) a basic scenario including depopulation of detected herds, 3km protection and 10km surveillance zones, movement tracing and a three-day national standstill, (2) the basic scenario plus depopulation in ring zones around detected herds (Depop), (3) the basic scenario plus protective vaccination within ring zones around detected herds, and (4) the basic scenario plus protective vaccination within ring zones around detected herds. Disease spread was simulated through direct animal movements, medium-risk contacts (veterinarians, artificial inseminators or milk controllers), low-risk contacts (animal feed and rendering trucks, technicians or visitors), market contacts, abattoir trucks, milk tanks, or local spread. The two simulation models showed different results in terms of the estimated numbers. However, the tendencies in terms of recommendations of strategies were similar for both models. Comparison of the different control strategies showed that, from an epidemiological point of view, protective vaccination would be preferable if the epidemic started in a cattle herd in an area with a high density of cattle, whereas if the epidemic started in an area with a low density of cattle or in other species, protective vaccination or depopulation would have almost the same preventive effect. Implementing additional control measures either 14 days after detection of the first infected herd or when 10 herds have been diagnosed would be more efficient than implementing additional control measures when more herds have been diagnosed. Protective vaccination scenarios would never be cost-effective, whereas depopulation or suppressive vaccination scenarios would most often be recommended. Looking at the median estimates of the cost-benefit analysis, depopulation in zones would most often be recommended, although, in extreme epidemics, suppressive vaccination scenarios could be less expensive. The vast majority of the costs and losses associated with a Danish epidemic could be attributed to export losses.
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 real-time 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
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Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems
Authors: Standardi, L. (Intern), Poulsen, N. K. (Intern), Jørgensen, J. B. (Intern), Sokoler, L. E. (Intern)
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Controlling Electricity Consumption by Forecasting its Response to Varying Prices

In a real-time electricity pricing context where consumers are sensitive to varying prices, having the ability to anticipate their response to a price change is valuable. This paper proposes models for the dynamics of such price-response, and shows how these dynamics can be used to control electricity consumption using a one-way price signal. Estimation of the price-response is based on data measurable at grid level, removing the need to install sensors and communication devices between each individual consumer and the price-generating entity. An application for price-responsive heating systems is studied based on real data, before conducting a control by price experiment using a mixture of real and synthetic data. With the control objective of following a constant consumption reference, peak heating consumption is reduced by nearly 5%, and 11% of the mean daily heating consumption is shifted.

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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Corradi, O. (Intern), Ochsenfeld, H. P. (Intern), Madsen, H. (Intern), Pinson, P. (Intern)
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Controlling traffic jams by time modulating the safety distance

The possibility of controlling traffic dynamics by applying high-frequency time modulation of traffic flow parameters is studied. It is shown that the region of the car density where the uniform (free) flow is unstable changes in the presence of time modulation compared with the unmodulated case. This region shrinks when the speed-up of cars does not exceed some critical value and expands in the opposite case. The flux of the time-modulated flow is an increasing function of the amplitude of the modulation for traffic flows whose density is larger than 1/h where h is the safety distance in the nonmodulated case, while it is a decreasing function in the opposite case. In other words, the safety distance time modulation facilitates car propagation in the case when the mean distance between cars in the congestive traffic is less than h and hinders it when the neighboring cars in the flow are well separated. A link between a microscopic description and the macroscopic fundamental diagram is established.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Department of Physics, Dynamical Systems, Bogolyubov Institute for Theoretical Physics, University of the Basque Country, AKAD University of Applied Sciences, Toyota Central R&D Labs
Authors: Gaididei, Y. B. (Ekstern), Gorria, C. (Ekstern), Berkemer, R. (Ekstern), Kawamoto, A. (Ekstern), Shiga, T. (Ekstern), Christiansen, P. L. (Intern), Sørensen, M. P. (Intern), Starke, J. (Intern)
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Scopus rating (2014): SJR 1.22 SNIP 1.123 CiteScore 2.05
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Scopus rating (2013): SJR 1.311 SNIP 1.239 CiteScore 2.28
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Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.69 SNIP 1.215
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Decentralized Large-Scale Power Balancing

A power balancing strategy based on Douglas-Rachford splitting is proposed as a control method for largescale 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.

General information

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Organisations: Department of Applied Mathematics and Computer Science, Scientific Computing, Dynamical Systems
Authors: Halvgaard, R. (Intern), Jørgensen, J. B. (Intern), Poulsen, N. K. (Intern), Madsen, H. (Intern), Vandenberghe, L. (Intern)
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Decisions on control of foot-and-mouth disease informed using model predictions

The decision on whether or not to change the control strategy, such as introducing emergency vaccination, is perhaps one of the most difficult decisions faced by the veterinary authorities during a foot-and-mouth disease (FMD) epidemic. A simple tool that may predict the epidemic outcome and consequences would be useful to assist the veterinary authorities in the decision-making process. A previously proposed simple quantitative tool based on the first 14 days outbreaks (FFO) of FMD was used with results from an FMD simulation exercise. Epidemic outcomes included the number of affected herds, epidemic duration, geographical size and costs. The first 14 days spatial spread (FFS) was also included to further support the prediction. The epidemic data was obtained from a Danish version (DTU-DADS) of a pre-existing FMD simulation model (Davis Animal Disease Spread – DADS) adapted to model the spread of FMD in Denmark. The European Union (EU) and Danish regulations for FMD control were used in the simulation. The correlations between FFO and FFS and the additional number of affected herds after day 14 following detection of the first infected herd were 0.66 and 0.82, respectively. The variation explained by the FFO at day 14 following detection was high (P-value < 0.001). This indicates that the FFO may take a part in the decision of whether or not to intensify FMD control, for instance by introducing emergency vaccination and/or pre-emptive depopulation, which might prevent a “catastrophic situation”. A significant part of the variation was explained by supplementing the model with the FFS (P-value < 0.001). Furthermore, the type of the index-herd was also a significant predictor of the epidemic outcomes (P-value < 0.05). The results of the current study suggest that national veterinary authorities should consider to model their national situation and to use FFO and FFS to help planning and updating their contingency plans and FMD emergency control strategies.
Decisions on foot-and-mouth disease control informed by model prediction
The predictive capability of the first fortnight incidence (FFI), which is the number of detected herds within the first 14 days following detection of the disease, of the course of a foot-and-mouth disease (FMD) epidemic and its outcomes were investigated. Epidemic outcomes included the number of affected herds, epidemic duration, geographical size, and costs. The first fourteen days spatial spread (FFS) was also included to support the prediction. The epidemic data were obtained from a Danish version (DTU-DADS) of the Davis Animal Disease Spread simulation model.

The FFI and FFS showed good correlations with the epidemic outcomes. The predictive capability of the FFI was high. This indicates that the FFI may take a part in the decision of whether or not to boost FMD control, which might prevent occurrence of a large epidemic in the face of an FMD incursion. The prediction power was improved by supplementing the models with information on FFS and characteristics of the index-herd. Results presented here will contribute to improve preparedness of Denmark to early control of a hypothetical FMD epidemic.

General information
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Organisations: National Veterinary Institute, Section for Epidemiology, Department of Applied Mathematics and Computer Science, Dynamical Systems
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Host publication information
Discrimination ability of the Energy score

Research on generating and verification of multivariate probabilistic forecasts has gained increased interest over the last few years. Emphasis is placed here on the evaluation of forecast quality with the Energy score, which is based on a quadratic scoring rule. While this score may be seen as appealing since being proper, we show that its discrimination ability may be limited when focusing on the dependence structure of multivariate probabilistic forecasts. For the case of multivariate Gaussian process, a theoretical upper for such discrimination ability is derived and discussed. This limited discrimination ability may eventually get compromised by computational and sampling issues, as dimension increases.

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Authors: Pinson, P. (Intern), Tastu, J. (Intern)
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Dynamical System Approaches to Combinatorial Optimization

Several dynamical system approaches to combinatorial optimization problems are described and compared. These include dynamical systems derived from penalty methods; the approach of Hopfield and Tank; self-organizing maps, that is, Kohonen networks; coupled selection equations; and hybrid methods. Many of them are investigated analytically, and the costs of the solutions are compared numerically with those of solutions obtained by simulated annealing and the costs of a global optimal solution.

Using dynamical systems, a solution to the combinatorial optimization problem emerges in the limit of large times as an asymptotically stable point of the dynamics. The obtained solutions are often not globally optimal but good approximations of it. Dynamical system and neural network approaches are appropriate methods for distributed and parallel processing. Because of the parallelization, these techniques are able to compute a given task much faster than algorithms which are using a traditional sequentially working digital
This chapter focuses on dynamical system approaches to the linear two-index assignment problem and the NP-hard three-index assignment problem. These and extensions thereof can be used as models for many industrial problems like manufacturing planning and optimization of flexible manufacturing systems. This is illustrated for an example in distributed robotic systems.
Exercise effects in a virtual type 1 diabetes patient: Using stochastic differential equations for model extension

The use of virtual patients for in silico testing of control algorithms for an artificial pancreas is growing. It is an easy, fast and low-cost alternative to pre-clinical testing. To simulate the everyday life of a type 1 diabetes (T1D) patient a simulator must be able to take into account physical activity. Exercise constitutes a substantial challenge to closed-loop control of
T1D. The effects are many and depend on intensity and duration and may be delayed by several hours. In this study, we use a model for the glucoregulatory system based on the minimal model and a previously published extension incorporating exercise effects on insulin and glucose dynamics. Our model is constructed as a stochastic state space model consisting of a set of stochastic differential equations (SDEs). In a stochastic state space model, the residual error is split into random measurement error and misspecification noise. The latter of the two can be used to pinpoint model deficiencies or unknown influential factors during the development of the model. The model is thus built on the basis of physiological knowledge of the system combined with information from observed data. Model parameters are estimated on clinical data from a study including exercise bouts of 20 minutes performed on 12 T1D patients treated with continuous subcutaneous insulin infusion. The predictive abilities of the model are investigated. In conclusion, this study illustrates the advantages of using SDEs in the development of an extended glucoregulatory model including effects of exercise suited for in silico testing.
Exotic states of bouncing and walking droplets

We present the results of an integrated experimental and theoretical investigation of droplets bouncing on a vibrating fluid bath. A comprehensive series of experiments provides the most detailed characterisation to date of the system's dependence on fluid properties, droplet size, and vibrational forcing. A number of new bouncing and walking states are reported, including complex periodic and aperiodic motions. Particular attention is given to the first characterisation of the different gaits arising within the walking regime. In addition to complex periodic walkers and limping droplets, we highlight a previously unreported mixed state, in which the droplet switches periodically between two distinct walking modes. Our experiments are complemented by a theoretical study based on our previous developments [J. Molacek and J. W. M. Bush, J. Fluid Mech.727, 582-611 (2013);10.1017/jfm.2013.279J. Molacek and J. W. M. Bush, J. Fluid Mech.727, 612-647 (2013)[10.1017/jfm.2013.280, which provide a basis for rationalising all observed bouncing and walking states.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Massachusetts Institute of Technology
Authors: Wind-Willassen, Ø. (Intern), Moláček, J. (Ekstern), Harris, D. M. (Ekstern), Bush, J. W. M. (Ekstern)
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BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.354 SNIP 1.348
Web of Science (2014): Indexed yes
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Scopus rating (2013): SJR 1.42 SNIP 1.395
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Experimental bifurcation analysis of an impact oscillator - Tuning a non-invasive control scheme

We investigate a non-invasive, locally stabilizing control scheme necessary for an experimental bifurcation analysis. Our test-rig comprises a harmonically forced impact oscillator with hardening spring nonlinearity controlled by electromagnetic actuators, and serves as a prototype for electromagnetic bearings and other machinery with build-in actuators. We propose a sequence of experiments that allows one to choose optimal control-gains, filter parameters and settings for a continuation method without a priori study of a model. Depending on the algorithm for estimating the Jacobian required by Newton's method we find two almost disjoint sets of suitable control parameters. Control-based continuation succeeds reliably in producing the full bifurcation diagram including both stable and unstable equilibrium states for an appropriately tuned controller.
Faraday waves in quasi-one-dimensional superfluid Fermi-Bose mixtures

The generation of Faraday waves in superfluid Fermi-Bose mixtures in elongated traps is investigated. The generation of waves is achieved by periodically changing a parameter of the system in time. Two types of modulations of parameters are considered: a variation of the fermion-boson scattering length and the boson-boson scattering length. We predict the properties of the generated Faraday patterns and study the parameter regions where they can be excited.
This article presents selected examples of model-based prediction and control of integrated sewer-wastewater treatment systems, developed within the framework of the Storm- and Wastewater Informatics project (SWI). By exploiting all the available on-line information (e.g. radar based rainfall measurements, flow and water levels, operational parameters at treatment plants) it is possible to dynamically optimize the integrated storm- and wastewater systems according to different criteria (e.g. utilizing the system fully at all times and reducing volumes of combined sewer overflows, loads of pollutants discharged from treatment plants, etc.). The tools developed in the SWI project include (but are not limited to (i) rainfall nowcasting based on radar measurements, (ii) probabilistic flow forecasting based on data assimilation and stochastic models, (iii) prediction and optimization of wet-weather performance of wastewater treatment plants, and (iv) integrated control of the different elements of the integrated wastewater systems. Full-scale testing of these tools in different catchment located in Denmark ensure that the developed tools can represent an important step forwards for on-line operation of combined sewer networks and wastewater treatment plants.
Forecasting Electricity Spot Prices Accounting for Wind Power Predictions

A two-step methodology for forecasting of electricity spot prices is introduced, with focus on the impact of predicted system load and wind power generation. The nonlinear and nonstationary influence of these explanatory variables is accommodated in a first step based on a nonparametric and time-varying regression model. In a second step, time-series models, i.e., ARMA and Holt–Winters, are applied to account for residual autocorrelation and seasonal dynamics. Empirical results are presented for out-of-sample forecasts of day-ahead prices in the Western Danish price area of Nord Pool's Elspot, during a two year period covering 2010–2011. These results clearly demonstrate the practical benefits of accounting for the complex influence of these explanatory variables.

Forecasting Production Losses at a Swedish Wind Farm

Production loss due to icing has been identified as a problem both when siting turbines in cold climates, and when making forecasts of energy production for wind park management and energy markets. The Makkonen icing model (Makkonen,
driven by output from the WRF mesoscale model, has been shown to predict periods of icing at a wind farm in northern Sweden (Davis et al, 2012) with improved skill compared to persistence and threshold models. Based on these results, we have developed a statistical model to estimate the loss of production at the wind park due to these icing periods. We compared this statistical model with a simpler method that does not rely on a physical icing model. In that method meteorological icing is identified as periods when WRF forecasts clouds and the temperature is below freezing. During these periods it is assumed that there is no production from the turbines, however as soon as the cloud goes away in the model we assume production returns to the idealized power curve. One unique aspect of the wind park we are working with is that it is not required to shut down when icing occurs. Therefore, during icing periods production still occurs, but below the idealized power curve. This enabled us to also examine how much production would have been lost had the turbines been required to shut down during the periods when they were iced.

**General information**

State: Published
Authors: Davis, N. (Intern), Hahmann, A. N. (Intern), Clausen, N. (Intern), Zagar, M. (Ekstern), Pinson, P. (Intern)
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**Forecasting the conditional dynamic elasticity of electricity consumers**

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Organisations: Department of Applied Mathematics and Computer Science, Department of Electrical Engineering, Center for Electric Power and Energy, Dynamical Systems
Authors: Pinson, P. (Intern), Madsen, H. (Intern)
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**Bibliographical note**
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.
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.

Grey-box Modeling for System Identification of Household Refrigerators: a Step Toward Smart Appliances

This paper presents the grey-box modeling of a vapor-compression refrigeration system for residential applications based on maximum likelihood estimation of parameters in stochastic differential equations. Models obtained are useful in the view of controlling refrigerators as flexible consumption units, which operation can be shifted within temperature and operational constraints. Even if the refrigerators are not intended to be used as smart loads, validated models are useful in predicting units consumption. This information can increase the optimality of the management of other flexible units, such as heat pumps for space heating, in order to smooth the load factor during peak hours, enhance reliability and efficiency in power networks and reduce operational costs.
Guideline Adherence of Antithrombotic Treatment Initiated by General Practitioners in Patients With Nonvalvular Atrial Fibrillation: A Danish Survey

Background The aim of this prospective survey was to describe the demographics, stroke risk profile, and the guideline adherence of antithrombotic treatment in a Danish primary care population of patients with nonvalvular atrial fibrillation (AF).

Hypothesis We hypothesized that a significant proportion of patients with nonvalvular AF do not receive guideline-adherent antithrombotic treatment in primary care.

Methods We performed a cross-sectional survey of antithrombotic treatment using data of AF patients from general practices.

Results Sixty-four general practitioners enrolled 1743 patients with a mean age of 74.8 ± 11.2 years. The mean CHADS(2) and CHA(2)DS(2)-VASc scores were 1.9 ± 1.3 and 3.5 ± 1.8, respectively. Of the patients, 12.4% and 4.04%, respectively, were at truly low risk, with a CHADS(2) and CHA(2)DS(2)-VASc score 0 (P < 0.001). A score of 1 was seen in 28.0% vs 9.0% (P < 0.001) of the patients. Of all patients, 66.3% were treated with oral anticoagulants, 18.7% with antiplatelet drugs only, and 15% received no antithrombotic therapy. Based on the CHADS(2) score, 75.7% of the patients were treated in adherence with the guidelines, 16% were undertreated, and 8.4% overtreated. The corresponding numbers for the CHA(2)DS(2)-VASc score were 75.4%, 22.7%, and 1.8%, respectively. The differences in guideline adherence applying the 2 scores were significant (P < 0.001). Of patients receiving no antithrombotic therapy, 64.1% were treated in adherence to the guidelines according to the CHADS(2) score. Applying the CHA(2)DS(2)-VASc score, this proportion was only 53.4%. Antiplatelet drug treatment was in adherence to the guidelines (CHADS(2) and CHA(2)DS(2)-VASc score of 1) in only 31% and 12% of the patients, respectively.

Conclusions Antithrombotic treatment of AF patients is in general well performed in primary care in Denmark. Further improvements may be achieved by thorough stroke risk stratification on the basis of current evidence-based guidelines.
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Web of Science (2013): Indexed yes
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Scopus rating (2012): SJR 0.662 SNIP 0.751 CiteScore 1.33
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.646 SNIP 0.587 CiteScore 1.1
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.552 SNIP 0.556
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.7 SNIP 0.744
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.521 SNIP 0.485
Scopus rating (2007): SJR 0.525 SNIP 0.552
Scopus rating (2006): SJR 0.576 SNIP 0.545
Scopus rating (2005): SJR 0.534 SNIP 0.505
Scopus rating (2004): SJR 0.535 SNIP 0.579
Scopus rating (2003): SJR 0.688 SNIP 0.682
Scopus rating (2002): SJR 0.663 SNIP 0.671
Scopus rating (2001): SJR 0.621 SNIP 0.681
Scopus rating (2000): SJR 0.633 SNIP 0.697
Scopus rating (1999): SJR 0.475 SNIP 0.638
Original language: English
Aged, Aged, 80 and over, Anticoagulants, Atrial Fibrillation, Chi-Square Distribution, Cross-Sectional Studies, Denmark, Drug Utilization Review, Female, Fibrinolytic Agents, General Practitioners, Guideline Adherence, Health Care Surveys, Humans, Male, Middle Aged, Physician's Practice Patterns, Platelet Aggregation Inhibitors, Practice Guidelines as Topic, Primary Health Care, Prospective Studies, Risk Assessment, Risk Factors, Stroke, CARDIAC, CLINICAL CLASSIFICATION SCHEMES, ACUTE ISCHEMIC-STROKE, EURO HEART SURVEY, RISK STRATIFICATION, NATIONAL REGISTRY, PREDICTING STROKE, TASK-FORCE, MANAGEMENT, WARFARIN, ANTICOAGULATION, anticoagulant agent, antithrombocytic agent, adult, aged, anticoagulant therapy, article, cardiovascular risk, cerebrovascular accident, female, general practice, general practitioner, health care survey, heart atrium fibrillation, human, major clinical study, male, practice guideline, primary medical care, prospective study, scoring system
DOIs:
10.1002/clc.22133
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Source-ID: 242966836
Publication: Research - peer-review › Journal article – Annual report year: 2014

Havvindmølleparker og deres indflydelse på fisk - et casestudy fra Horns Rev havvindmøllepark

General information
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Organisations: National Institute of Aquatic Resources, Section for Ecosystem based Marine Management, Section for Marine Living Resources, Department of Applied Mathematics and Computer Science, Dynamical Systems
Publication date: 2013
Event: Abstract from 17. Danske havforskermøde, Roskilde, Denmark.
Main Research Area: Technical/natural sciences
Publication: Research › Conference abstract for conference – Annual report year: 2013
Impact of Wind Power Generation on European Cross-Border Power Flows
A statistical analysis is performed in order to investigate the relationship between wind power production and cross-border power transmission in Europe. A dataset including physical hourly cross-border power exchanges between European countries as dependent variables is used. Principal component analysis is employed in order to reduce the problem dimension. Then, nonlinear relationships between forecast wind power production as well as spot price in Germany, by far the largest wind power producer in Europe, and power flows are modeled using local polynomial regression. We find that both forecast wind power production and spot price in Germany have substantial nonlinear effects on power transmission on a European scale.
Implementation of an integrated real-time control system of sewer system and waste water treatment plant in the city of Wilhelmshaven

A case study for integrated real-time control (RTC) of an urban drainage system in the city of Wilhelmshaven (Germany) is explained. The fuzzy based RTC strategy combines control of the sewer system and inflow to the waste water treatment plant. The main objective in controlling the sewer system is to reduce the number of overflows and the volume at a combined sewer overflow (CSO), located close to a bathing beach. Based on online measurements, the operation mode of two pumping stations is modified. This approach allows the safe activation of free storage volume in the sewer system without constructive measures. To avoid critical situations in the treatment process, the inflow to the treatment plant is automatically reduced to a defined value if high inflows to the treatment plant occur in combination with unfavorable conditions on the secondary clarifiers during rainfall events. The integrated RTC system has been operational for approximately one year.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Institut für technisch-wissenschaftliche Hydrologie GmbH
Authors: Seggelke, K. (Ekstern), Löwe, R. (Intern), Beeneken, T. (Ekstern), Fuchs, L. (Ekstern)
Pages: 330–341
Publication date: 2013
Main Research Area: Technical/natural sciences

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Journal: Urban Water Journal
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BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.689 SNIP 1.192 CiteScore 1.87
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.583 SNIP 1.141 CiteScore 1.42
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.625 SNIP 2.033 CiteScore 1.67
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.705 SNIP 1.074 CiteScore 1.58
Informal uncertainty analysis (GLUE) of continuous flow simulation in a hybrid sewer system with infiltration inflow - Consistency of containment ratios in calibration and validation?

Monitoring of flows in sewer systems is increasingly applied to calibrate urban drainage models used for long-term simulation. However, most often models are calibrated without considering the uncertainties. The generalized likelihood uncertainty estimation (GLUE) methodology is here applied to assess parameter and flow simulation uncertainty using a simplified lumped sewer model that accounts for three separate flow contributions: wastewater, fast runoff from paved areas, and slow infiltrating water from permeable areas. Recently GLUE methodology has been critisised for generating prediction limits without statistical coherence and consistency and for the subjectivity in the choice of a threshold value to distinguish "behavioural" from "non-behavioural" parameter sets. In this paper we examine how well the GLUE methodology performs when the behavioural parameter sets deduced from a calibration period are applied to generate prediction bounds in validation periods. By retaining an increasing number of parameter sets we aim at obtaining consistency between the GLUE generated 90% prediction limits and the actual containment ratio (CR) in calibration. Due to the large uncertainties related to spatiooral rain variability during heavy convective rain events, flow measurement errors, possible model deficiencies as well as epistemic uncertainties, it was not possible to obtain an overall CR of more than 80%. However, the GLUE generated prediction limits still proved rather consistent, since the overall CRs obtained in calibration corresponded well with the overall CRs obtained in validation periods for all proportions of retained parameter sets evaluated. When focusing on wet and dry weather periods separately, some inconsistencies were however found between calibration and validation and we address here some of the reasons why we should not expect the coverage of the prediction limits to be identical in calibration and validation periods in real-world applications. The large uncertainties result in wide posterior parameter limits, that cannot be used for interpretation of, for example, the relative size of paved area vs. the size of infiltrating area. We should therefore try to learn from the significant discrepancies between model and observations from this study, possibly by using some form of non-stationary error correction procedure, but it seems crucial to obtain more representative rain inputs and more accurate flow observations to reduce parameter and model simulation uncertainty. © Author(s) 2013.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Department of Environmental Engineering, Urban Water Engineering, Dynamical Systems
Authors: Breinholt, A. (Intern), Grum, M. (Intern), Madsen, H. (Intern), Thordarson, F. Ø. (Intern), Mikkelsen, P. S. (Intern)
Pages: 4159-4176
Publication date: 2013
Main Research Area: Technical/natural sciences

Publication information
Journal: Hydrology and Earth System Sciences
Volume: 17
Inhomogeneous Markov Models for Describing Driving Patterns

It has been predicted that electric vehicles will play a crucial role in incorporating a large renewable component in the energy sector. If electric vehicles are integrated in a naive way, they may exacerbate issues related to peak demand and transmission capacity limits while not reducing polluting emissions. Optimizing the charging of electric vehicles is paramount for their successful integration. This paper presents a model to describe the driving patterns of electric vehicles, in order to provide primary input information to any mathematical programming model for optimal charging. Specifically, an inhomogeneous Markov model that captures the diurnal variation in the use of a vehicle is presented. The model is defined by the time-varying probabilities of starting and ending a trip and is justified due to the uncertainty associated with the use of the vehicle. The model is tied to data collected from the actual utilization of a vehicle. Inhomogeneous Markov models imply a large number of parameters. The number of parameters in the proposed model is reduced using B-splines.

Investigating the use of stochastic forecast for RTC of urban drainage systems

Real time control is considered a mean to efficiently improve the performance of urban drainage systems. A globally optimal utilisation of e.g. storage volume in basins can best be achieved by considering runoff forecasts in the decision setup. These forecasts, however, are subject to significant uncertainty. This uncertainty should be considered in the decision making. An approach that incorporates stochastic multistep runoff predictions from so-called greybox models into a real time control setup is presented. These models provide a dynamic description of forecast uncertainties and they simultaneously allow a continuous adaption of the model states to observed runoff. Methods for generating stochastic forecasts and incorporating these into the decision making framework are described. Using two sample events, the forecast quality is compared to state-of-the-art deterministic forecasting models and the effect on control decisions and the resulting overflow volume is evaluated. We can demonstrate potential of the stochastic models but identify a need for model adaptivity and modified model structures that allow for a more general modelling of forecast uncertainties.
Projects:
Investigating the use of stochastic forecast for RTC of urban drainage systems
Source: dtu
Source-ID: u::7794
Publication: Research - peer-review › Paper – Annual report year: 2013

Investigating the use of stochastic forecasts for RTC of urban drainage systems

General information
State: Published
Organisations: Department of Environmental Engineering, Department of Applied Mathematics and Computer Science, Dynamical Systems, Krüger A/S
Authors: Vezzaro, L. (Intern), Löwe, R. (Intern), Madsen, H. (Intern), Grum, M. (Ekstern), Mikkelsen, P. S. (Intern)
Number of pages: 11
Publication date: 2013

Publication information
Media of output: PowerPoint
Original language: English
Main Research Area: Technical/natural sciences

Relations
Activities:
Investigating the use of stochastic forecast for RTC of urban drainage systems
Publication: Research › Sound/Visual production (digital) – Annual report year: 2013

Kanalnetz- und Kläranlagenzuflusssteuerung am Beispiel des Einzugsgebiets Wilhelmshaven
In the catchment area of the Wilhelmshaven wastewater treatment plant, an integrated, fuzzy-based control system has been in place for more than a year now. The system’s essential elements are a sewer network control system to reduce stormwater overflow events and volumes at a sensitive sewage disposal point as well as the control of the wastewater treatment plant’s inflow as a function of measurement values during the treatment process in order to avoid critical load conditions. The accompanying monitoring shows that operating experiences are positive and it confirms a more than 25% reduction in overall stormwater overflow volumes at the sensitive sewage disposal point only thanks to the implementation of the control system. Moreover, the safe operation of the wastewater treatment plant can be guaranteed by simple means without significantly increasing stormwater overflow discharges. Currently the concept, which up to now is partly based on values obtained by hand-held measuring devices, is broadened by installing additional on-line measurement technology in the wastewater treatment plant.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Institut für technisch-wissenschaftliche Hydrologie GmbH, TBW Wilhelmshaven
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Number of pages: 9
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Main Research Area: Technical/natural sciences

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BFI (2016): BFI-level 1
BFI (2015): BFI-level 1
BFI (2014): BFI-level 1
BFI (2013): BFI-level 1
ISI indexed (2013): ISI indexed no
Load forecasting for supermarket refrigeration

This report presents a study of models for forecasting the load for supermarket refrigeration. The data used for building the forecasting models consists of load measurements, local climate measurements and weather forecasts. The load measurements are from a supermarket located in a village in Denmark. The load for refrigeration is the sum of all cabinets in the supermarket, both low and medium temperature cabinets, and spans a period of one year. As input to the forecasting models the ambient temperature observed near the supermarket together with weather forecasts are used. Every hour the hourly load for refrigeration for the following 42 hours is forecasted. The forecast models are adaptive linear time-series models which are fitted with a computationally efficient recursive least squares scheme. The dynamic relations between the inputs and the load is modeled by simple transfer functions. The system operates in two regimes: one in the closing hours during night and one in the opening hours during the day. This is modeled by a regime switching model in which some of the coefficients in the model depends on the regime. The results show that the one-step ahead residuals are close to white noise, however some dependence on the ambient temperature remains, which is caused by non-linearities in the relation between the load and the ambient temperature. Suggestions for including these non-linearities are given in the discussion of the results.

The report starts with a section in which the data and the NWPs are described. This is followed by a presentation of the modeling approach and the model identification, where a suitable forecasting model is found. Finally, the results are presented, and the method is discussed and conclusions are drawn.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, ENFOR A/S
Authors: Bacher, P. (Intern), Madsen, H. (Intern), Aalborg Nielsen, H. (Ekstern)
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Publisher: DTU Compute
Original language: English

Number: 2013-08
ISSN: 1601-2321
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Electronic versions:
tr13_08_2ed_Bacher_P.pdf
Publication: Research › Report – Annual report year: 2013

Low-energy house in Sisimiut - Data overview

Experiments with persistently exciting heat inputs are a fundamental tool in identification of heat dynamics in buildings. The Low-energy house in Sisimiut, Greenland, provides an advanced experimental setup with frequent measurements of temperatures, heat inputs, and much more. This paper presents an overview of data collected since the installation of the new measurement and control system. Focus is on heat dynamics so only data related to that will be shown. 5 experiments have been conducted. They are described, and resulting data is shown.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Civil Engineering, Section for Building Physics and Services
Authors: Andersen, P. H. D. (Intern), Rode, C. (Intern), Madsen, H. (Intern)
Number of pages: 19
Low-energy house in Sisimiut - Measurement equipment

This paper documents the measurement equipment in a low-energy house in Sisimiut, Greenland. Detailed measurements are being taken on energy consumption, indoor temperatures, floor heating, ventilation, open/closed state of doors and windows, and indoor climate. Equipped with a central control unit, experiments can be designed in order to study heat dynamics of the building. It is described how to plan and execute such experiments in one apartment in the building. The building also features both a solar thermal system and extra buffer tank facilitating testing of storage strategies on the power generated by the solar thermal system. A weather station equipped with thermometer, pyranometer and anemometer is installed on the building as well. Finally, it is described how to retrieve data from an SQL server which is configured to take monthly backups. R functions have been implemented to fetch and prepare the data for time series analysis. Examples are given on the use of these.

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
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Center for Energy Resources Engineering, Scientific Computing, Copenhagen University Hospital
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Main Research Area: Technical/natural sciences

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Volume: 7
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Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.14 SJR 0.804 SNIP 1.124
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.855 SNIP 0.897 CiteScore 1.99
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.871 SNIP 0.971 CiteScore 1.84
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.78 SNIP 0.918 CiteScore 2.19
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.69 SNIP 0.972 CiteScore 1.33
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.687 SNIP 0.916 CiteScore 0.6
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.452 SNIP 0.683
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.24 SNIP 0.539
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.228 SNIP 0.422
Original language: English
Links:
http://www.jdst.org/
Source: dtu
Source-ID: u::8559
Publication: Research - peer-review › Journal article – Annual report year: 2013

Model Identification Using Stochastic Differential Equation Grey-Box Models in Diabetes

BACKGROUND:
The acceptance of virtual preclinical testing of control algorithms is growing and thus also the need for robust and reliable
models. Models based on ordinary differential equations (ODEs) can rarely be validated with standard statistical tools. Stochastic differential equations (SDEs) offer the possibility of building models that can be validated statistically and that are capable of predicting not only a realistic trajectory, but also the uncertainty of the prediction. In an SDE, the prediction error is split into two noise terms. This separation ensures that the errors are uncorrelated and provides the possibility to pinpoint model deficiencies.

METHODS:
An identifiable model of the glucoregulatory system in a type 1 diabetes mellitus (T1DM) patient is used as the basis for development of a stochastic-differential-equation-based grey-box model (SDE-GB). The parameters are estimated on clinical data from four T1DM patients. The optimal SDE-GB is determined from likelihood-ratio tests. Finally, parameter tracking is used to track the variation in the "time to peak of meal response" parameter.

RESULTS:
We found that the transformation of the ODE model into an SDE-GB resulted in a significant improvement in the prediction and uncorrelated errors. Tracking of the "peak time of meal absorption" parameter showed that the absorption rate varied according to meal type.

CONCLUSION:
This study shows the potential of using SDE-GBs in diabetes modeling. Improved model predictions were obtained due to the separation of the prediction error. SDE-GBs offer a solid framework for using statistical tools for model validation and model development.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Center for Energy Resources Engineering, Scientific Computing, Novo Nordisk A/S, Copenhagen University Hospital
Authors: Duun-Henriksen, A. K. (Intern), Schmidt, S. (Forskerdatabase), Røge, R. M. (Ekstern), Møller, J. B. (Ekstern), Nørgaard, K. (Forskerdatabase), Jørgensen, J. B. (Intern), Madsen, H. (Intern)
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Web of Science (2017): Indexed yes
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Scopus rating (2016): CiteScore 2.14 SJR 0.804 SNIP 1.124
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.855 SNIP 0.897 CiteScore 1.99
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.871 SNIP 0.971 CiteScore 1.84
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.78 SNIP 0.918 CiteScore 2.19
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.69 SNIP 0.972 CiteScore 1.33
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.687 SNIP 0.916 CiteScore 0.6
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.452 SNIP 0.683
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.24 SNIP 0.539
Modelling the Effect of Exercise on Insulin Pharmacokinetics in "Continuous Subcutaneous Insulin Infusion" Treated Type 1 Diabetes Patients

Introduction: The artificial pancreas is believed to ease the burden of constant management of type 1 diabetes for the patients substantially. An important aspect of the artificial pancreas development is the mathematical models used for control, prediction or simulation. A major challenge to the realization of the artificial pancreas is the effect of exercise on the insulin and plasma glucose dynamics. In this report, we take the first step towards a population model of exercise effects in type 1 diabetes. We focus on the effect on the insulin pharmacokinetics in continuous subcutaneous insulin infusion (CSII) treated patients by modelling the absorption rate as a function of exercise.

Methods: Three models are estimated from 17 data sequences. All of them are based on a linear three-compartment base model. The models are based on stochastic differential equations to allow noise to enter the dynamics. In the first model, the insulin absorption rate parameter is replaced by a random walk. In the second model, the relationship between the absorption rate and exercise is modelled as a linear dependency, while in the third model this linear relationship depends on the intensity. A Lamperti transformation is used to ensure non-negative state values. A special focus is put on the structural identifiability of the base model, while the posterior identifiability is checked for all models from the conditional likelihood profiles.

Results: The first model is disregarded due to the small number of observations during the exercise bout. From likelihood-ratio tests and information criteria, the third model is appointed as the best model to model the relationship between exercise and the insulin absorption. The posterior identifiability check showed that it was not possible to identify the variance of the measurement variance.

Conclusion: A model to predict the insulin appearance in plasma during exercise in CSII treated patients is identified. Further clinical studies are needed to confirm the increase in insulin plasma concentration during exercise in type 1 diabetes patients. These studies should include dense sampling to allow for a fully data driven identification of an appropriate model.

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.

Models for the energy performance of low-energy houses
The aim of this thesis is data-driven modeling of heat dynamics of buildings. Traditionally, thermal modeling of buildings is done using simulation tools which take information about the construction, weather data, occupancy etc. as inputs and generate deterministic energy profiles of the buildings. This approach often fails in predicting the actual heat consumption of buildings once they are constructed. The approach taken in this work is deriving models from observations collected after the construction, aiming at describing the actual characteristics of the building.

Identification of heat dynamics of buildings is needed both in order to assess energy-efficiency and to operate modern buildings economically. Energy signatures are a central tool in both energy performance assessment and decision making related to refurbishment of buildings. Also for operation of modern buildings with installations such as mechanical ventilation, floor heating, and control of the lighting effect, the heat dynamics must be taken into account. Hence, this thesis provides methods for data-driven modeling of heat dynamics of modern buildings.

While most of the work in this thesis is related to characterization of heat dynamics of buildings, the first topic analyzed is the variation of presence of occupants. As buildings get more energy-efficient, internal loads and user-behavior increasingly influence the energy consumption. Most simulation tools use deterministic occupancy profiles to simulate internal loads. However, such occupancy patterns will largely depend on the specific use of the building, and hence the profiles must be empirically based. A probabilistic method for modeling time-dependence and dynamics of presence of occupants is developed and applied by estimation and model validation on data from an office building. The approach to modeling occupants’ presence provides a flexible method where no assumptions in the application.

The rest of the thesis deals with statistical modeling of heat dynamics of buildings. First, discrete-time models are applied. Discrete-time models are computationally relatively simple and provide a flexible framework for dynamical modeling as a natural extension of the often-used static energy-balance models. The importance of applying dynamical models, even for deriving thermostatic or steady-state properties, is stressed, and methods for doing so are outlined.

Since heat transfer is fundamentally described by partial differential equations, modeling of heat dynamics using differential equations is an obvious approach. A quasi-Gaussian maximum likelihood estimation technique, where the likelihood function is evaluated using the extended Kalman filter on state-space models, is used. In this framework - referred to as “grey-box” modeling - one-step predictions can be generated and used for model validation by testing statistically whether the model describes all variation and dynamics observed in the data. The possibility of validating the model dynamics is a great advantage from the use of stochastic differential equations compared to ordinary differential equations.

The strengths of the discrete-time and the continuous-time approach are discussed. Besides the parametrization, which is directly physically interpretable, grey-box models intrinsically provide variable prediction uncertainty, which is important in relation to design of controllers and decision making for comfort requirements. In the framework of stochastic differential equations, there are normally more parameters related to noise processes than in discrete-time models which increases the complexity of the estimation. Here, the state space formulation is often used. Since there is normally infinitely many
state space representations corresponding to a transfer function model, structural identifiability is important in relation to state space modeling.

A low-energy building in Sisimiut, Greenland is used as a test-building. The building is well-insulated and features large modern energy-efficient windows and floor heating. These features lead to increased non-linear responses to solar radiation and longer time constants. The building is equipped with advanced control and measuring equipment. Experiments are designed and performed in order to identify important dynamical properties of the building, and the collected data is used for modeling.

The thesis emphasizes the statistical model building and validation needed to identify dynamical systems. It distinguishes from earlier work by focusing on modern low-energy construction and going further into studying and characterizing the dynamical properties of the fitted models.

General information
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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Civil Engineering, Section for Building Physics and Services
Authors: Andersen, P. H. D. (Intern), Madsen, H. (Intern), Rode, C. (Intern)
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Publication: Research › Ph.D. thesis – Annual report year: 2013

Monitoring and characterizing offshore wind variability with weather radars for wind energy applications

General information
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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Electrical Engineering, Center for Electric Power and Energy
Authors: Trombe, P. (Intern), Pinson, P. (Intern)
Number of pages: 18
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Original language: English
Main Research Area: Technical/natural sciences
Source: dtu
Source-ID: u::10040
Publication: Research › Sound/Visual production (digital) – Annual report year: 2013

Online load forecasting for supermarket refrigeration
This paper presents a study of models for forecasting the load for supermarket refrigeration. The data used for building the forecasting models consists of load measurements, local climate measurements and weather forecasts. The load measurements are from a supermarket located in a village in Denmark. Every hour the hourly load for refrigeration for the following 42 hours is forecasted. The forecast models are time adaptive linear time-series models. The dynamic relations between the inputs and the load is modeled by simple transfer functions. The system operates in two regimes: one in the closing hours during night and one in the opening hours during the day. This is modeled by a regime switching model in which some of the coefficients in the model depends on the regime. The results show that the one-step ahead residuals are close to white noise, however it is found that some non-linear dependence on the ambient temperature should be included in the model in further work.
Online short-term heat load forecasting for single family houses

This paper presents a method for forecasting the load for heating in a single-family house. Both space and hot tap water heating are forecasted. The forecasting model is built using data from sixteen houses in Sønderborg, Denmark, combined with local climate measurements and weather forecasts. Every hour the hourly heat load for each house the following two days is forecasted. The forecast models are adaptive linear time-series models and the climate inputs used are: ambient temperature, global radiation, and wind speed. A computationally efficient recursive least squares scheme is used. The models are optimized to fit the level of optimal adaptivity and the thermal dynamical response of the building. Identification of a model, which is suitable for application to all the houses, is carried out. The results show that the forecasting errors mainly are related to: unpredictable high frequency variations in the heat load signal (predominant only for some houses), peaks presumably from showers, shifts in resident behavior, and uncertainty of the weather forecasts for longer horizons, especially for the solar radiation.

On the best learning algorithm for web services response time prediction

In this article we will examine the effect of different learning algorithms, while training the MLP (Multilayer Perceptron) with the intention of predicting web services response time. Web services do not necessitate a user interface. This may seem contradictory to most people’s concept of what an application is. A Web service is better imagined as an application “segment,” or better as a program enabler. Performance is an important quality aspect of Web services because of their distributed nature. Predicting the response of web services during their operation is very important.
Optimal vaccination scenarios against vector-borne diseases

Using a process oriented semi-agent based model we simulated the spread of Bluetongue virus in Denmark. We evaluated the efficiency and minimum vaccination cover for eight different preventive vaccination strategies in Denmark.

The simulation model replicates both passive and active flight of Culicoides between hosts on pasture and stables in Denmark. Seasonal abundance of midges and temperature dependence on biological processes were included in the model. The eight vaccination scenarios comprised of: All holdings vaccinated to a given percentage, random holdings selected for vaccination, two scenarios based on the size of holdings, mosaic vaccination of nearest neighbor farms, vaccination of hosts on pasture, regional vaccination, and trench vaccination from the border to Germany. These eight scenarios were investigated under normal grazing conditions and under a forced housing scenario.

The most robust vaccination scenarios were all holdings vaccinated and the mandatory vaccination of hosts on pasture. Regional vaccination and trench vaccination display better results under some conditions, but are very sensitive to the incursion route.

With this study we intended to test scenarios that would increase distance between infectious and susceptible hosts. This can be done very efficiently on a regional scale if the incursion route is well specified. However as the long-range spread of midge borne disease is still poorly quantified, more robust national vaccination schemes seems preferable.

Results in this presentation were obtained building upon the model presented in: Simulating spread of Bluetongue Virus by flying vectors between hosts on pasture. Kaare Græsbøll et al. Scientific Reports. 2:863 (2012).

Optimization Under Uncertainty for Management of Renewables in Electricity Markets

This thesis deals with the development and application of models for decision-making under uncertainty to support the participation of renewables in electricity markets.

The output of most renewable sources, e.g., wind, is intermittent and, furthermore, it can only be predicted with a limited accuracy. As a result of their non-dispatchable and stochastic nature, the management of renewables poses new challenges as compared to conventional sources of electricity. Focusing in particular on short-term electricity markets, both the trading activities of market participants (producers, retailers and consumers) and the decision-making processes of system and market operators are challenged.

As far as producers are concerned, participation in electricity markets imposes them to make their trading decisions with a
certain advance in time as compared to energy delivery. Since their actual output is uncertain at the time of bidding, the trading problem for a renewable power producer translates into a stochastic optimization problem, whose objective is the maximization of the expected revenues. In this thesis, we consider the trading problem for a wind power producer both in markets with low penetration of renewables, where the producer is a price-taker, and in markets where the producer acts as a price-maker.

Owing to the demand response initiatives to be undertaken in future power systems, the operation of electricity retailers and the behavior of consumers are also going to be influenced by renewable power production. Another focus of this thesis is on time-varying price mechanisms to make the most of end consumers' flexibility. In particular, the problem of managing optimally a virtual power plant equipped with renewable production facilities and flexible consumers is addressed through control-by-price. In a similar setup, the optimal trading (and pricing) problem for a retailer connected to flexible consumers is considered.

Finally, market and system operators are challenged by the increasing penetration of renewables, which put stress on markets that were designed to accommodate a generation mix largely dominated by conventional sources. Indeed, the traditional market design, based on the sequential clearing of successive market floors and on deterministic rules and criteria, is characterized by higher and higher degrees of suboptimality and lower reliability as the penetration of renewables increases. This work contributes to the state-of-the-art by proposing new mechanisms for day-ahead dispatch and reserve determination in markets with high penetration of renewables, on the basis of stochastic criteria.

Pool Strategy of a Price-Maker Wind Power Producer
We consider the problem of a wind power producer trading energy in short-term electricity markets. The producer is a price-taker in the day-ahead market, but a price-maker in the balancing market, and aims at optimizing its expected revenues from these market floors. The problem is formulated as a mathematical program with equilibrium constraints (MPEC) and cast as a mixed-integer linear program (MILP), which can be solved employing off-the-shelf optimization software. The optimal bid is shown to deliver significantly improved performance compared to traditional bids such as the conditional mean or median forecast of wind power distribution. Finally, sensitivity analyses are carried out to assess the impact on the offering strategy of the producer's penetration in the market, of the correlation between wind power production and residual system deviation, and of the shape of the forecast distribution of wind power production.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Electrical Engineering
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Authors: Zugno, M. (Intern), Morales González, J. M. (Intern), Pinson, P. (Intern), Madsen, H. (Intern)
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**PossPOW: possible Power of Downregulated Offshore Wind Power Plants**

**General information**
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, Department of Applied Mathematics and Computer Science, Dynamical Systems, Aeroelastic Design
Authors: Göçmen, T. (Intern), Giebel, G. (Intern), Sørensen, P. E. (Intern), Poulsen, N. K. (Intern), Réthoré, P. (Intern), Mirzaei, M. (Intern)
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**PossPOW: Possible Power of Downregulated Offshore Wind Power Plants**

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**POSSPOW: Possible Power of 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.

Radial sine-Gordon kinks as sources of fast breathers
We consider radial sine-Gordon kinks in two, three, and higher dimensions. A full two-dimensional simulation showing that azimuthal perturbations remain small allows us to reduce the problem to the one-dimensional radial sine-Gordon equation. We solve this equation on an interval \([r, r_1]\) and absorb all outgoing radiation. As the kink shrinks toward \(r\), before the collision, its motion is well described by a simple law derived from the conservation of energy. In two dimensions for \(r \leq 2\), the collision disintegrates the kink into a fast breather, while for \(r \geq 4\) we obtain a kink-breather metastable state where breathers are shed at each kink “return.” In three and higher dimensions \(d\), an additional kink-oscillon state appears for small \(r\). On the application side, the kink disintegration opens the way for new types of terahertz microwave generators.
Regime-based supervisory control to reduce power fluctuations from offshore wind power plants

Wind power fluctuations, especially offshore, can pose challenges in the secure and stable operation of the power system. In modern large offshore wind farms, there are supervisory controls designed to reduce the power fluctuations. Their operation is limited due to the fact that they imply loss of production, hence revenue for the wind farm operator. On the other hand, progresses in short term forecasting, together with the increasing use of probabilistic forecasting can help in achieving efficient power fluctuations reduction with minimum lost production. Here we present supervisory control
concepts that consider different wind power regimes to derive control setpoints by using a Markov-Switching AutoRegressive model. We evaluate the performance versus measured data in terms of power ramp characteristics and energy efficiency.

**General information**
State: Published
Organisations: Department of Wind Energy, Wind Energy Systems, Department of Applied Mathematics and Computer Science, Dynamical Systems, Center for Electric Power and Energy
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Publication: Research - peer-review › Article in proceedings – Annual report year: 2013

**Reliability in the utility computing era: Towards reliable Fog computing**
This paper considers current paradigms in computing and outlines the most important aspects concerning their reliability. The Fog computing paradigm as a non-trivial extension of the Cloud is considered and the reliability of the networks of smart devices are discussed. Combining the reliability requirements of grid and cloud paradigms with the reliability requirements of networks of sensor and actuators it follows that designing a reliable Fog computing platform is feasible.

**General information**
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Télécom ParisTech, Spiru Haret University, “UNESCO Chair” Department, Academy of Sciences
Authors: Madsen, H. (Intern), Burtschy, B. (Ekstern), Albeanu, G. (Ekstern), Popentiu-Vladicescu, F. (Ekstern)
Pages: 43-46
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**Short-term heat load forecasting for single family houses**
This paper presents a method for forecasting the load for space heating in a single-family house. The forecasting model is built using data from sixteen houses located in Sønderborg, Denmark, combined with local climate measurements and weather forecasts. Every hour the hourly heat load for each house the following two days is forecasted. The forecast models are adaptive linear time-series models and the climate inputs used are: ambient temperature, global radiation and wind speed. A computationally efficient recursive least squares scheme is used. The models are optimized to fit the individual characteristics for each house, such as the level of adaptivity and the thermal dynamical response of the building, which is modeled with simple transfer functions. Identification of a model, which is suitable for all the houses, is carried out. The results show that the one-step ahead errors are close to white noise and that practically all correlation to the climate variables are removed. Furthermore, the results show that the forecasting errors mainly are related to: unpredictable high frequency variations in the heat load signal (predominant only for some houses), shifts in resident behavior patterns and uncertainty of the weather forecasts for longer horizons, especially for solar radiation.
Short-term wind power forecasting: probabilistic and space-time aspects

Optimal integration of wind energy into power systems calls for high quality wind power predictions. State-of-the-art forecasting systems typically provide forecasts for every location individually, without taking into account information coming from the neighbouring territories. It is however intuitively expected that owing to the inertia in meteorological systems such local approach to power forecasting is sub-optimal. Indeed, errors in meteorological forecasts might translate to fronts of imbalances, i.e. taking the form of a band of forecast errors propagating across entire regions.

My research work deals with the proposal and evaluation of new mathematical models and forecasting methods for short-term wind power forecasting, accounting for space-time dynamics based on geographically distributed information. Different forms of power predictions are considered, starting from traditional point forecasts, then extending to marginal predictive densities and, finally, considering multivariate space-time trajectories.

Point predictions is the most classical approach to wind power forecasting, only providing single-valued estimates of the expected future power generation. The objective is to introduce a statistical model which would improve the quality of state-of-the-art prediction methods by accounting for the fact that forecasts errors made by such locally-optimized forecasting methods propagate in space and in time under the influence of prevailing weather conditions.

Subsequently, the extension from point to probabilistic forecasts is dealt with, hence requiring to describe the uncertainty associated with the point predictions previously generated. Both parametric and non-parametric approaches to forming predictive densities are considered, while ways to include space-time effects into the corresponding models are analysed.

As a final step, emphasis is placed on generating space-time trajectories: this calls for the prediction of joint multivariate predictive densities describing wind power generation at a number of distributed locations and for a number of successive lead times.

In addition to new improved approaches to wind power forecasting, a part of the research is devoted to problems related to the assessment of high-dimensional (multivariate) probabilistic forecasts.
**Simulated effects of changes in herd sizes and densities with regard to fmd outbreaks in Denmark**

**General information**
State: Published
Organisations: National Veterinary Institute, Section for Epidemiology, Department of Applied Mathematics and Computer Science , Dynamical Systems
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Electronic versions:
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**Simulation of annual electric lighting demand using various occupancy profiles**
This paper describes an investigation of the effect on electric lighting demand of applying occupancy models of various resolution to climate-based daylight modelling. The lighting demand was evaluated for a building zone with the occupant always present, with occupancy corresponding to absence factors, based on an estimated annual mean occupancy, based on estimated 1-hour mean occupancy, and based on 2-min occupancy intervals. The results showed little difference in the annual electric lighting demand when the same occupancy profile was used every day, as opposed to when profiles were used where occupancy varied every day. Furthermore, the results showed that annual electric lighting demand was evaluated slightly conservatively when a mean absence factor was applied as opposed to using dynamic occupancy profiles.

**General information**
State: Published
Organisations: Section for Building Physics and Services, Department of Civil Engineering, Department of Applied Mathematics and Computer Science , Dynamical Systems
Authors: Iversen, A. (Intern), Andersen, P. H. D. (Intern), Svendsen, S. (Intern), Nielsen, T. R. (Intern)
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Web of Science (2017): Indexed yes
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Simulation of Listeria monocytogenes single cell colonial growth

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ISBN (Print): 978-2-35670-025-4
Main Research Area: Technical/natural sciences

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Poster presentation
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Sizing of Microparticles from Angular Scattering Ratio
This technical note deals with light scattering measurements for sizing of micrometer-scale particles in a suspension.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Scientific Computing
Authors: Hjorth, P. G. (Intern), Karamehmedovic, M. (Intern)
Number of pages: 2
Publication date: 2013
Solar/electric heating systems for the future energy system

The project “Solar/electric heating systems in the future energy system” was carried out in the period 2008-2013. The project partners were DTU Byg, DTU Informatics (now DTU Compute), DMI, ENFOR A/S and COWI A/S. The companies Ajva ApS, Ohmatex ApS and Innogie ApS worked together with the project partners in two connected projects in order to develop solar/electric heating systems for laboratory tests. The project was financed by the Danish Agency for Science, Technology and Innovation under the Danish Council for Strategic Research in the program Sustainable Energy and Environment. The DSF number of the project is 2104-07-0021/09-063201/DSF. This report is the final report of the project.

The aim of the project is to elucidate how individual heating units for single family houses are best designed in order to fit into the future energy system. The units are based on solar energy, electrical heating elements/heat pump, advanced heat storage tanks and advanced control systems.

Heat is produced by solar collectors in sunny periods and by electrical heating elements/heat pump. The electrical heating elements/heat pump will be in operation in periods where the heat demand cannot be covered by solar energy. The aim is to use the auxiliary heating units when the electricity price is low, e.g. due to large electricity production by wind turbines.

The unit is equipped with an advanced control system where the control of the auxiliary heating is based on forecasts of the electricity price, the heat demand and the solar energy production. Consequently, the control is based on weather forecasts.

Three differently designed heating units are tested in a laboratory test facility. The systems are compared on the basis of:
- energy consumption for the auxiliary heating
- energy cost for the auxiliary heating
- net utilized solar energy

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Organisations: Department of Civil Engineering, Section for Building Physics and Services, Department of Applied Mathematics and Computer Science, Dynamical Systems, Center for Energy Resources Engineering, Scientific Computing, Department of Electrical Engineering, Danish Meteorological Institute, COWI A/S, Innogie ApS
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Space-time scenarios of wind power generation produced using a Gaussian copula with parametrized precision matrix

The emphasis in this work is placed on generating space-time trajectories (also referred to as scenarios) of wind power generation. This calls for prediction of multivariate densities describing wind power generation at a number of distributed locations and for a number of successive lead times. A modelling approach taking advantage of sparsity of precision matrices is introduced for the description of the underlying space-time dependence structure. The proposed parametrization of the dependence structure accounts for such important process characteristics as non-constant conditional precisions and direction-dependent cross-correlations. Accounting for the space-time effects is shown to be crucial for generating high quality scenarios.
State-space adjustment of radar rainfall and skill score evaluation of stochastic volume forecasts in urban drainage systems

Merging of radar rainfall data with rain gauge measurements is a common approach to overcome problems in deriving rain intensities from radar measurements. We extend an existing approach for adjustment of C-band radar data using state-space models and use the resulting rainfall intensities as input for forecasting outflow from two catchments in the Copenhagen area. Stochastic grey-box models are applied to create the runoff forecasts, providing us with not only a point forecast but also a quantification of the forecast uncertainty. Evaluating the results, we can show that using the adjusted radar data improves runoff forecasts compared with using the original radar data and that rain gauge measurements as forecast input are also outperformed. Combining the data merging approach with short-term rainfall forecasting algorithms may result in further improved runoff forecasts that can be used in real time control.
Flow forecast, Grey-box model, Radar rainfall, State-space model

Statistical aspects of fish stock assessment

Fish stock assessments are conducted for two main purposes: 1) To estimate past and present fish abundances and their commercial exploitation rates. 2) To predict the consequences of different management strategies in order to ensure a sustainable fishery in the future.

This thesis concerns statistical aspects of fish stocks assessment, which includes topics such as time series analysis, generalized additive models (GAMs), and non-linear state-space/mixed models capable of handling missing data and a high number of latent states and parameters. The aim is to improve the existing methods for stock assessment by application of state-of-the-art statistical methodology. The main contributions are presented in the form of six research papers.

The major part of the thesis deals with age-structured assessment models, which is the most common approach.
Conversion from length to age distributions in the catches is a necessary step in age-based stock assessment models. For this purpose, GAMs and continuation ratio logits are combined to model the probability of age as a smooth function of length and spatial coordinates, which constitutes an improvement over traditional methods based on area-stratification. GAMs and delta-distributions are applied for the calculation of indices of abundance from trawl survey data, and different error structures for these are investigated.

Two extensions to the state-space approach to age-structured stock assessment modelling are presented. The first extension introduces multivariate error distributions on survey catch-at-age data. The second extension is an integrated assessment model for overlapping sub-stocks subject to joint exploitation in the area of overlap. Estimation and inference is carried out using maximum likelihood.

Finally, a biomass dynamic model based on stochastic differential equations is presented. This work extends the classical approaches to biomass modelling by incorporating observation errors on the catches, and allowing for missing and non-equidistant samples in time.

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Statistical Modelling of Wind Profiles - Data Analysis and Modelling
The aim of the analysis presented in this document is to investigate whether statistical models can be used to make very short-term predictions of wind profiles.

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Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Electrical Engineering, Center for Electric Power and Energy
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Stochastic control of traffic patterns
A stochastic modulation of the safety distance can reduce traffic jams. It is found that the effect of random modulation on congestive flow formation depends on the spatial correlation of the noise. Jam creation is suppressed for highly correlated noise. The results demonstrate the advantage of heterogeneous performance of the drivers in time as well as individually.
This opens the possibility for the construction of technical tools to control traffic jam formation.
Stochastic Differential Equations in Artificial Pancreas Modelling

Type 1 diabetes accounts for approximately 5% of the total diabetes population. It is caused by the destruction of insulin producing β-cells in the pancreas. Various treatment strategies are available today, some of which include advanced technological devices such as an insulin pump and a continuous glucose monitor (CGM). Despite these technological advances in the treatment of type 1 diabetes, the disease still poses an enormous and constant challenge for the patients. To obtain tight glucose control the patients are required to assess how much they will eat prior to the meal. They have to assess the timing, intensity and duration of physical exercise in advance, to adjust the insulin dose accordingly. Additionally, several uncontrollable and unpredictable factors such as stress, hormonal cycles and sickness changing the metabolic state make this task even more difficult.

The development of the insulin pump and the CGM has paved the way for a fully automatic treatment regime, the artificial pancreas. The idea is to connect the CGM with the insulin pump via a control algorithm running on e.g. the patients smart phone. The CGM observations are sent to the smart phone and based on this information, the control algorithm computes the optimal dose adjustment and sends instructions to the insulin pump.

To develop control algorithms, mathematical models of the physiological dynamics are needed. They attempt to describe the significant dynamics of the system and hence they approximate the system behavior. However, uncertainty in the model occurs due to the nature of physiological systems and due to the presence of unknown disturbances. An attractive approach to deal with this uncertainty is to use stochastic differential equations (SDEs). In a model based on SDEs, the noise is separated into two terms: 1) a diffusion term occurring from model misspecifications, effects of unknown disturbances, or just true stochastic behavior of the system and 2) a measurement noise term representing the serially uncorrelated error occurring due to the imperfect analysing equipment. The diffusion term affects the evolution of the system directly.

The purpose of this PhD-project was to investigate the potential of SDEs in the artificial pancreas development. Especially, the emerging continuous monitoring of glucose levels makes SDEs highly applicable to this field. The current thesis aims at demonstrating and discussing the benefits and challenges by using SDEs compared to traditional methods on the basis of the results of the project.

First of all, we designed a clinical study to obtain high quality data from type 1 diabetes patients to identify the models from. The study included the main factors influencing the glucose level: insulin boluses, meals, and exercise. A modelling study showed that using SDEs in model development can be advantageous in several ways. We were able to pinpoint model deficiencies in a well-known model and to track parameter variation probably caused by a differences in meal type. This information could be added to the model to improve the fit. The study was limited by the lack of a software capable of handling SDE models of population effects instead of single-subject effects. A prototype of this type of software was developed parallel to the end of the project. Thus, we could finally identify a population model of the effect of exercise on the insulin absorption rate. The small amount of observations made it impossible to use SDEs to track parameter variation. Instead, we formulated a model structure with showed to be significantly better than the base model with a constant rate.

Two studies specifically related to the CGM observations were performed during the project. In the first study, we showed that SDEs could be used to tune a control algorithm for overnight glucose control on the basis of CGM observations. The tuned algorithm improved the controller performance in a subsequent clinical study. Further attempts to deal with the problems related to the CGM included a Bayesian estimation scheme. By incorporating prior knowledge about the uncertainty in the CGM observations into the estimation method, we succeeded in predicting the plasma glucose level with acceptable confidence from the CGM observations only.

Overall, the project confirms that SDEs have a large potential within this field. However, future modeling requires a robust software capable of handling the nonlinear population SDE models. When this is available, larger modeling studies can be initiated and the impact of SDEs would be expected to increase.
Stochastic runoff forecasting and real time control of urban drainage systems

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Environmental Engineering, Urban Water Engineering
Authors: Löwe, R. (Intern), Vezzaro, L. (Intern), Grum, M. (Ekstern), Mikkelsen, P. S. (Intern), Madsen, H. (Intern)
Number of pages: 1
Publication date: 2013
Main Research Area: Technical/natural sciences
Electronic versions:
20121213_Abstract_FINAL.pdf
Links:
http://www.forskningsplatformenvand.dk/Documents/Annual%20meeting%202013/Presentations/Session%206/Roland%20Lowe_Presentation_DWRiP_FINAL.pdf
Source: dtu
Source-ID: u::6987
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2013

Stochastic runoff forecasting and real time control of urban drainage systems

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Environmental Engineering
Authors: Löwe, R. (Intern), Vezzaro, L. (Intern), Grum, M. (Intern), Mikkelsen, P. S. (Intern), Madsen, H. (Intern)
Number of pages: 17
Publication date: 2013

Publication information
Media of output: PowerPoint
Original language: English
Main Research Area: Technical/natural sciences

Relations
Activities:
Stochastic runoff forecasting and real time control of urban drainage systems
Publication: Research - peer-review › 2D/3D (physical products) – Annual report year: 2013

Stokastiske prognoser for afløb og real tids styring

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Environmental Engineering, Urban Water Engineering
Authors: Löwe, R. (Intern), Madsen, H. (Intern), Mikkelsen, P. S. (Intern)
Pages: 17-18
Publication date: 2013
Main Research Area: Technical/natural sciences

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Journal: EVA : Erfaringsudveksling i vandmiljøteknikken
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Issue number: 2
ISSN (Print): 1901-3663
Ratings:
Stokastiske prognoser for afløb og real tids styring

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Environmental Engineering, Urban Water Engineering
Authors: Löwe, R. (Intern), Vezzaro, L. (Intern), Mikkelsen, P. S. (Intern), Grum, M. (Intern), Madsen, H. (Intern)
Pages: 11-16
Publication date: 2013
Main Research Area: Technical/natural sciences

Strategies for fitting nonlinear ecological models in R, AD Model Builder, and BUGS
Ecologists often use nonlinear fitting techniques to estimate the parameters of complex ecological models, with attendant frustration. This paper compares three open-source model fitting tools and discusses general strategies for defining and fitting models. R is convenient and (relatively) easy to learn, AD Model Builder is fast and robust but comes with a steep learning curve, while BUGS provides the greatest flexibility at the price of speed. Our model-fitting suggestions range from general cultural advice (where possible, use the tools and models that are most common in your subfield) to specific suggestions about how to change the mathematical description of models to make them more amenable to parameter estimation. A companion web site (https://groups.nceas.ucsb.edu/nonlinear-modeling/projects) presents detailed examples of application of the three tools to a variety of typical ecological estimation problems; each example links both to a detailed project report and to full source code and data.

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, National Institute of Aquatic Resources, Section for Marine Living Resources, McMaster University, USGS Patuxent Wildlife Research Center, Inter-American Tropical Tuna Commission, University of Florida, National Center for Ecological Analysis and Synthesis, Harvard University, French National Centre for Scientific Research, Dalhousie University, University of California at Berkeley, University of Tasmania, Swiss Ornithological Institute, University of Hawaii, Marine Research Institute, University of Ottawa, University of British Columbia, University of Bergen
Authors: Bolker, B. (Ekstern), Gardner, B. (Ekstern), Maunder, M. (Ekstern), Berg, C. W. (Intern), Brooks, M. (Ekstern), Comita, L. (Ekstern), Crane, E. (Ekstern), Cubaynes, S. (Ekstern), Davies, T. (Ekstern), Valpine, P. D. (Ekstern), Ford, J. (Ekstern), Gimenez, O. (Ekstern), Kéry, M. (Ekstern), Kim, E. (Ekstern), Lennert-Cody, C. (Ekstern), Magnusson, A. (Ekstern), Martell, S. (Ekstern), Nash, J. (Ekstern), Nielsen, A. (Intern), Regetz, J. (Ekstern), Skaug, H. (Ekstern), Zipkin, E. (Ekstern)
Pages: 501-512
Publication date: 2013
Main Research Area: Technical/natural sciences
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Journal: Methods in Ecology and Evolution  
Volume: 4  
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BFI (2017): BFI-level 2  
Web of Science (2017): Indexed yes  
BFI (2016): BFI-level 2  
Web of Science (2016): Indexed yes  
Scopus rating (2016): CiteScore 7.28 SJR 4.733 SNIP 2.621  
BFI (2015): BFI-level 1  
Scopus rating (2015): SJR 5.382 SNIP 2.842 CiteScore 7.61  
Web of Science (2015): Indexed yes  
BFI (2014): BFI-level 1  
Scopus rating (2014): SJR 4.112 SNIP 2.452 CiteScore 6.29  
Web of Science (2014): Indexed yes  
BFI (2013): BFI-level 1  
Scopus rating (2013): SJR 3.011 SNIP 2.427 CiteScore 5.34  
ISI indexed (2013): ISI indexed yes  
Web of Science (2013): Indexed yes  
Scopus rating (2012): SJR 2.106 SNIP 1.648 CiteScore 3.56  
ISI indexed (2012): ISI indexed no  
Web of Science (2012): Indexed yes  
Original language: English  
Electronic versions:  
Publishers version  
DOIs:  
10.1111/2041-210X.12044  
Links:  
Publication: Research - peer-review › Journal article – Annual report year: 2014

**Subdural to subgaleal EEG signal transmission: The role of distance, leakage and insulating affectors**

**Objective**

To estimate the area of cortex affecting the extracranial EEG signal. Methods The coherence between intra- and extracranial EEG channels were evaluated on at least 10 min of spontaneous, awake data from seven patients admitted for epilepsy surgery work up.

**Results**

Cortical electrodes showed significant extracranial coherent signals in an area of approximately 150 cm² although the field of vision was probably only 31 cm² based on spatial averaging of intracranial channels taking into account the influence of the craniotomy and the silastic membrane of intracranial grids. Selecting the best cortical channels, it was possible to increase the coherence values compared to the single intracranial channel with highest coherence. The coherence seemed to increase linearly with an accumulation area up to 31 cm², where 50% of the maximal coherence was obtained accumulating from only 2 cm² (corresponding to one channel), and 75% when accumulating from 16 cm².

**Conclusion**

The skull is an all frequency spatial averager but dominantly high frequency signal attenuator. Significance An empirical assessment of the actual area of cerebral sources generating the extracranial EEG provides better opportunities for clinical electroencephalographers to determine the location of origin of particular patterns in the EEG.

**General information**

State: Published  
Organisations: Department of Electrical Engineering, Biomedical Engineering, Department of Applied Mathematics and Computer Science, Dynamical Systems, Hypo-Safe A/S, Copenhagen University Hospital, University of Copenhagen  
Authors: Duun-Henriksen, J. (Intern), Kjaer, T. W. (Ekstern), Madsen, R. E. (Ekstern), Jespersen, B. (Forskerdatabase), Duun-Henriksen, A. K. (Intern), Remvig, L. S. (Ekstern), Thomsen, C. E. (Ekstern), Sørensen, H. B. D. (Intern)  
Pages: 1570-1577
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 probability 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 is 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
Authors: Petersen, L. N. (Intern), Poulsen, N. K. (Intern), Niemann, H. H. (Intern), Utzen, C. (Ekstern), Jørgensen, J. B. (Intern)
Number of pages: 1
Publication date: 2013
Event: Abstract from 18th Nordic Process Control Workshop, Oulu, Finland.
Main Research Area: Technical/natural sciences
Spray drying, Multi-Stage dryer, Grey-box model, First-principles model
Electronic versions:
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Abstract
Source: dtu
Source-ID: u::10078
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2013

The range of attraction for light traps catching Culicoides biting midges

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Cryptology, Dynamical Systems, National Veterinary Institute, Section for Epidemiology, Statistics and Data Analysis
Authors: Græsbøll, K. (Intern), Kirkeby, C. (Intern), Bødker, R. (Intern), Stockmarr, A. (Intern), Christiansen, L. E. (Intern), Lind, P. (Intern)
Number of pages: 1
Publication date: 2013
Event: Poster session presented at EDENext Annual Meeting, Barcelona, Spain.
Main Research Area: Technical/natural sciences
Electronic versions:
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The range of attraction for light traps catching Culicoides biting midges

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, National Veterinary Institute, Section for Epidemiology, Statistics and Data Analysis
Authors: Græsbøll, K. (Intern), Kirkeby, C. (Intern), Bødker, R. (Intern), Stockmarr, A. (Intern), Christiansen, L. E. (Intern), Lind, P. (Intern)
Number of pages: 1
Publication date: 2013
Main Research Area: Technical/natural sciences

The range of attraction for light traps catching Culicoides biting midges (Diptera: Ceratopogonidae)

Background
Culicoides are vectors of e.g. bluetongue virus and Schmallenberg virus in northern Europe. Light trapping is an important tool for detecting the presence and quantifying the abundance of vectors in the field. Until now, few studies have investigated the range of attraction of light traps.

Methods
Here we test a previously described mathematical model (Model I) and two novel models for the attraction of vectors to light traps (Model II and III). In Model I, Culicoides fly to the nearest trap from within a fixed range of attraction. In Model II Culicoides fly towards areas with greater light intensity, and in Model III Culicoides evaluate light sources in the field of view and fly towards the strongest. Model II and III incorporated the directionally dependent light field created around light traps with fluorescent light tubes. All three models were fitted to light trap collections obtained from two novel experimental setups in the field where traps were placed in different configurations.

Results
Results showed that overlapping ranges of attraction of neighboring traps extended the shared range of attraction. Model I did not fit data from any of the experimental setups. Model II could only fit data from one of the setups, while Model III fitted data from both experimental setups.

Conclusions
The model with the best fit, Model III, indicates that Culicoides continuously evaluate the light source direction and intensity. The maximum range of attraction of a single 4W CDC light trap was estimated to be approximately 15.25 meters. The attraction towards light traps is different from the attraction to host animals and thus light trap catches may not represent the vector species and numbers attracted to hosts.

General information
State: Published
Organisations: National Veterinary Institute, Section for Epidemiology, Department of Applied Mathematics and Computer Science, Cryptology, Dynamical Systems, Statistics and Data Analysis
Authors: Kirkeby, C. (Intern), Græsbøll, K. (Intern), Stockmarr, A. (Intern), Christiansen, L. E. (Intern), Bødker, R. (Intern)
Number of pages: 19
Publication date: 2013
Main Research Area: Technical/natural sciences

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Journal: Parasites & Vectors
Volume: 6
Issue number: 67
ISSN (Print): 1756-3305
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BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.23 SJR 1.458 SNIP 1.286
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.676 SNIP 1.381 CiteScore 3.61
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.51 SNIP 1.576 CiteScore 3.31
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.541 SNIP 1.46 CiteScore 3.52
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.213 SNIP 1.333 CiteScore 3.43
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.068 SNIP 1.317 CiteScore 3.06
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.972 SNIP 1.008
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.867 SNIP 0.812
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Original language: English
Culicoides, Range of attraction, Vector abundance, Light traps, Vector monitoring
Electronic versions:
1756_3305_6_67.pdf
DOIs:
10.1186/1756-3305-6-67

Bibliographical note
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Relations
Projects:
The range of attraction for light traps catching Culicoides biting midges (Diptera: Ceratopogonidae)
Source: dtu
Source-ID: u::7314
Publication: Research - peer-review › Journal article – Annual report year: 2013

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
State: Published
Organisations: Center for Energy Resources Engineering, Department of Applied Mathematics and Computer Science, Dynamical Systems
The smart grid research network: Road map for Smart Grid research, development and demonstration up to 2020

This road map is a result of part-recommendation no. 25 in ‘MAIN REPORT – The Smart Grid Network’s recommendations’, written by the Smart Grid Network for the Danish Ministry of Climate, Energy and Building in October 2011. This part-recommendation states:

“Part-recommendation 25 – A road map for Smart Grid research, development and demonstration
It is recommended that the electricity sector invite the Ministry to participate in the creation of a road map to ensure that solutions are implemented and coordinated with related policy areas. The sector should also establish a fast-acting working group with representatives from universities, distribution companies and the electric industry, in order to produce a mutual, binding schedule for the RDD of the Smart Grid in Denmark.

Time prioritisation of part-recommendation: 2011-2012
Responsibility for implementation of part-recommendation: Universities, along with relevant electric-industry actors, should establish a working group for the completion of a consolidated road map by the end of 2012.”

In its work on this report, the Smart Grid Research Network has focused particularly on part-recommendations 26, 27 and 28 in ‘MAIN REPORT – The Smart Grid Network’s recommendations’, which relate to strengthening and marketing the research infrastructure that will position Denmark as the global hub for Smart Grid development; strengthening basic research into the complex relationships in electric systems with large quantities of independent parties; and improved understanding of consumer behaviour and social economics. Naturally the work has spread to related areas along the way. The work has been conducted by the Smart Grid Research Network.

Using forecast information for storm ride-through control

General information
Using forecast information for storm ride-through control

Using probabilistic forecast information in control algorithms can improve the performance of wind farms during periods of extreme winds. This work presents a wind farm supervisor control concept that uses probabilistic forecast information to ride-through a storm with softer ramps of power. Wind speed forecasts are generated with a statistical approach (i.e. time series models). The supervisor control is based on a set of logical rules that consider point forecasts and predictive densities to ramp-down the power of the wind farm before the storm hits. The potential of this supervisor control is illustrated with data from the Horns Rev 1 wind farm, located in the North Sea. To conclude, an overview of ongoing and future research in the Radar@Sea experiment is given. This experiment aims at improving offshore wind power predictability and controllability through the increased use of meteorological information, and particularly weather radar images.

Viscoelastic Modelling of Road Deflections for use with the Traffic Speed Deflectometer

This Ph.D. study is at its core about how asphalt and road structures responds to dynamic loads. Existing models for the deflections under a moving load using beam equations are revisited and it is concluded they leave room for improvement for the particular setup and problem at hand. Then a different approach is set up to model visco-elastic deflections starting from the physically based framework of continuum mechanics by using Finite Element Methods (FEM) combined with the Laplace transform. It is shown that this approach coincides with a more standard time-stepping FEM setup in the case of a generalized Maxwell model.

Validations by comparison to ViscoRoute simulations are also made. This justifies the use of the Laplace FEM for generating simulated data using a Huet-Sayegh model for the visco-elastic behaviour of asphalt. These simulated data, along with measured data, are then used to suggest an approach for a computationally simpler synthetic model capturing essential behaviour of deflection bassins under a moving wheel.

Additionally the setup allows for simulated comparisons of the cases of loadings emulating the use of a Falling Weight Deflectometer with loadings emulating a moving wheel as in the case of using a Traffic Speed Deflectometer. The
flexibility of the method also allows for looking into cases excluded by imposing simplifying assumptions such as the structure imagined to be an infinite halfspace.

Weather radars for wind energy applications

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, Department of Electrical Engineering, Center for Electric Power and Energy, Department of Wind Energy, Wind Energy Systems, Danish Meteorological Institute
Authors: Trombe, P. (Intern), Pinson, P. (Intern), Vedel, H. (Ekstern), Barahona Garzón, B. (Intern), Madsen, H. (Intern)
Number of pages: 1
Publication date: 2013
Event: Poster session presented at Danish Wind Power Research 2013, Fredericia, Denmark.
Main Research Area: Technical/natural sciences
Electronic versions:
trombe_etal_poster_DWEC_2013.pdf
Publication: Research › Poster – Annual report year: 2013

Wind Power Forecasting with a Focus on Risk and Uncertainties

General information
State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems, ENFOR A/S
Authors: Madsen, H. (Intern), Zugno, M. (Intern), Pinson, P. (Intern), Aalborg Nielsen, H. A. N. (Ekstern), Skov Nielsen, T. (Ekstern)
Number of pages: 26
Publication date: 2013

Publication information
Media of output: PowerPoint
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions:
Wind_Power_Forecasting_Henrik_Madsen.pdf
Publication: Research › Sound/Visual production (digital) – Annual report year: 2013

A formal statistical approach to representing uncertainty in rainfall-runoff modelling with focus on residual analysis and probabilistic output evaluation - Distinguishing simulation and prediction

While there seems to be consensus that hydrological model outputs should be accompanied with an uncertainty estimate the appropriate method for uncertainty estimation is not agreed upon and a debate is ongoing between advocates of formal statistical methods who consider errors as stochastic and GLUE advocates who consider errors as epistemic, arguing that the basis of formal statistical approaches that requires the residuals to be stationary and conform to a statistical distribution is unrealistic. In this paper we take a formal frequentist approach to parameter estimation and
uncertainty evaluation of the modelled output, and we attach particular importance to inspecting the residuals of the model outputs and improving the model uncertainty description. We also introduce the probabilistic performance measures sharpness, reliability and interval skill score for model comparison and for checking the reliability of the confidence bounds. Using point rainfall and evaporation data as input and flow measurements from a sewer system for model conditioning, a state space model is formulated that accounts for three different flow contributions: wastewater from households, and fast rainfall-runoff from paved areas and slow rainfall-dependent infiltration-inflow from unknown sources. We consider two different approaches to evaluate the model output uncertainty, the output error method that lumps all uncertainty into the observation noise term, and a method based on Stochastic Differential Equations (SDEs) that separates input and model structure uncertainty from observation uncertainty and allows updating of model states in real-time. The results show that the optimal simulation (off-line) model is based on the output error method whereas the optimal prediction (on-line) model is based on the SDE method and the skill scoring criterion proved that significant predictive improvements of the output can be gained from updating the states continuously. In an effort to attain residual stationarity for both the output error method and the SDE method transformation of the observations were necessary but the statistical assumptions were nevertheless not 100% justified. The residual analysis showed that significant autocorrelation was present for all simulation models. We believe users of formal approaches to uncertainty evaluation within hydrology and within environmental modelling in general can benefit significantly from adopting the evaluation measures applied here, so the probabilistic performance of their models can be assessed properly. (C) 2012 Elsevier B.V. All rights reserved.

General information
State: Published
Organisations: Department of Environmental Engineering, Department of Applied Mathematics and Computer Science, Dynamical Systems, Urban Water Engineering
Authors: Breinholt, A. (Intern), Møller, J. K. (Intern), Madsen, H. (Intern), Mikkelsen, P. S. (Intern)
Pages: 36-52
Publication date: 2012
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Hydrology
Volume: 472-473
ISSN (Print): 0022-1694
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.89 SJR 1.745 SNIP 1.759
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.708 SNIP 1.771 CiteScore 3.54
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.679 SNIP 2.005 CiteScore 3.45
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.71 SNIP 1.997 CiteScore 3.36
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.924 SNIP 2.016 CiteScore 3.38
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.753 SNIP 1.858 CiteScore 3.16
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.784 SNIP 1.714
A new ensemble model for short term wind power prediction

As the objective of this study, a non-linear ensemble system is used to develop a new model for predicting wind speed in short-term time scale. Short-term wind power prediction becomes an extremely important field of research for the energy sector. Regardless of the recent advancements in the re-search of prediction models, it was observed that different models have different capabilities and also no single model is suitable under all situations. The idea behind EPS (ensemble prediction systems) is to take advantage of the unique features of each subsystem to detain diverse patterns that exist in the dataset. The conferred results show that the prediction errors can be decreased, while the computation time is reduced.

General information

State: Published
Organisations: Department of Applied Mathematics and Computer Science, Dynamical Systems
Authors: Madsen, H. (Intern), Albu, R. (Ekstern), Felea, I. (Ekstern), Popentiu-Vladicescu, F. (Ekstern)
Pages: 1505-1514
Publication date: 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
Authors: Mirzaei, M. (Intern), Poulsen, N. K. (Intern), Niemann, H. H. (Intern)
Number of pages: 3
Publication date: 2012
Main Research Area: Technical/natural sciences
Wind turbines, Trailing edge aps, Integrated design, Youla parameterization

Integrated Wind Power Planning Tool

This poster describes the status as of April 2012 of the Public Service Obligation (PSO) funded project PSO 10464 "Integrated Wind Power Planning Tool". The project goal is to integrate a meso scale numerical weather prediction (NWP) model with a statistical tool in order to better predict short term power variation from off shore wind farms, as well as to conduct forecast error assessment studies in preparation for later implementation of such a feature in an existing simulation model. The addition of a forecast error estimation feature will further increase the value of this tool, as it's output can be fed into any type of system model or decision-making problem that wish to account for forecast errors in the planning process, rather than assume perfect forecasts.

General information
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Organisations: Department of Wind Energy, Meteorology, Department of Applied Mathematics and Computer Science, Dynamical Systems, Wind Energy Systems, ENFOR A/S
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Integrated Wind Power Planning Tool

This poster presents the current state of the public service obligation (PSO) funded project PSO 10464 "Integrated Wind Power Planning Tool". The project commenced October 1, 2011, and the goal is to integrate a numerical weather prediction (NWP) model with purely statistical tools in order to assess wind power fluctuations, with focus on long term power system planning for future wind farms as well as short term forecasting for existing wind farms. Currently, wind power fluctuation models are either purely statistical or integrated with NWP models of limited resolution. With regard to the latter, one such simulation tool has been developed at the Wind Energy Division, Risø DTU, intended for long term power system planning. As part of the PSO project the inferior NWP model used at present will be replaced by the state-of-the-art Weather Research & Forecasting (WRF) model. Furthermore, the integrated simulation tool will be improved so it can handle simultaneously 10-50 times more turbines than the present 300, as well as additional atmospheric parameters will be included in the model. The WRF data will also be input for a statistical short term prediction model to be developed in collaboration with ENFOR A/S; a danish company that specialises in forecasting and optimisation for the energy sector. This integrated prediction model will allow for the description of the expected variability in wind power production in the coming hours to days, accounting for its spatio-temporal dependencies, and depending on the prevailing weather conditions de ned by the WRF output.

The output from the integrated prediction tool constitute scenario forecasts for the coming period, which can then be fed into any type of system model or decision making problem to be solved. The high resolution of the WRF results loaded
into the integrated prediction model will ensure a high accuracy data basis is available for use in the decision making process of the Danish transmission system operator, and the need for high accuracy predictions will only increase over the next decade as Denmark approaches the goal of 50% wind power based electricity in 2020, from the current 20%.

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**Modelling spread of Bluetongue and other vector borne diseases in Denmark and evaluation of intervention strategies**
The main outcome of this PhD project is a generic model for non-contagious infectious vector-borne disease spread by one vector species between up to two species of hosts distributed on farms and pasture. The model features a within-herd model of disease, combined with a triple movement kernel that describes spread of disease using vectors or hosts as agents of the spread.

The model is run with bluetongue as the primary case study, and it is demonstrated how an epidemic outbreak of bluetongue 8 in Denmark is sensitive to the use of pasture, climate, vaccination, vector abundance, and flying parameters.

In constructing a more process oriented agent-based approach to spread modeling new parameters describing vector behavior were introduced. When these vector flying parameters have been quantified by experiments, this model can be implemented on areas naïve to the modeled disease with a high predictive power.

Furthermore this PhD has provided a new method of estimating the effect of light traps, which can estimate the additive effect of closely placed traps, and determine trap range of individual traps based on emitted light intensity. Moreover there has been devised a method to sample in time which maximizes information about time dependence and is robust to changes.

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**Publication information**
Model Predictive Control Algorithms for Pen and Pump Insulin Administration

Despite recent developments within diabetes management such as rapid-acting insulin, continuous glucose monitors (CGM) and insulin pumps, tight blood glucose control still remains a challenge. A fully automated closed-loop controller, also known as an artificial pancreas (AP), has the potential to ease the life and reduce the risk of acute and chronic diabetic complications. However, the noise associated to CGMs, the long insulin action time for continuous subcutaneous infusion of insulin (CSII) pumps, and the high intra- and inter-patient variability significantly limits the performance of current closed-loop controllers.

In this thesis, we present different control strategies based on Model Predictive Control (MPC) for an artificial pancreas. We use Nonlinear Model Predictive Control (NMPC) in order to determine the optimal insulin and blood glucose profiles. The optimal control problem (OCP) is solved using a multiple-shooting based algorithm. We use an explicit Runge-Kutta method (DOPRI45) with an adaptive stepsize for numerical integration and sensitivity computation. The OCP is solved using a Quasi-Newton sequential quadratic programming (SQP) with a linesearch and a BFGS update for the Hessian of the Lagrangian. In addition, we apply a Continuous-Discrete Extended Kalman Filter (CDEKF) in order to simulate cases where the meal size is uncertain, or even unannounced.

We also propose a novel control strategy based on linear MPC for overnight stabilization of blood glucose. The model parameters are personalized using a priori available patient information. We consider an autoregressive integrated moving average with exogenous input (ARIMAX) model. We summarize and the results of the overnight clinical studies conducted at Hvidovre Hospital. Based on these results, we propose improvements for the stochastic part of our controller model. We state and compare three different stochastic model structures. The first one is the ARIMAX structure that has been used for the clinical studies. The second one is an autoregressive moving average with exogenous input (ARMAX) model. The third one is an adaptive ARMAX model in which we estimate the parameters of the stochastic part using a Recursive Least Square (RLS) method. We test the controller in a virtual clinic of 100 patients. This virtual clinic is based on the Hovorka model. We consider the case where only half of the bolus is administrated at mealtime, and the case where the insulin sensitivity increases during the night.

This thesis consists of a summary report, glucose and insulin profiles of the clinical studies and research papers submitted, peer-reviewed and/or published in the period September 2009 - September 2012.
New statistical approaches with consideration for extremes

Optical characterisation of nanostructures using a discretised forward model

Optical diffraction microscopy (ODM) is a non-destructive and relatively inexpensive means of characterisation of nanostructures. It is an essential tool in the design, production and quality control of functional nanomaterials. In ODM, the target is reconstructed from the measured optical power in the reflected far field. This inverse scattering problem is typically highly ill-posed due to the incompleteness of the data and the low signal-to-noise ratio. In a realistic setting, the formulation of the forward scattering model is usually complicated by the presence of supporting structures (e.g., a substrate or a grid supporting a nanoparticle), since the electromagnetic interaction between the nanostructure and the supporting structure must be taken into account. Also, the roughness and the contamination of the supporting structure can increase the dimensionality and the ill-posedness of the inverse problem. Finally, the size of the measured nanostructure is typically comparable to the wavelength of the illuminating light, so the scattering needs to be described using the full Maxwellian electromagnetic model, rather than (numerically inexpensive) asymptotic formulations.

We here describe an efficient, accurate and robust forward scattering model [1,2] based on discrete sources and tailor-made for the reconstruction of 2D nanoparticles on substrates from ODM data. We adopt an analysis-based modelling paradigm, and attempt to incorporate as much available a priori information as possible directly in the forward model. We replace the classical radiation integrals by finite linear combinations of stratified Green's functions for the Helmholtz operator in the plane, and thus achieve a sparse formulation and an implicit description of the particle-substrate interaction. The forward model can be extended to include the roughness and contamination of the substrate without sacrificing the speed of computation [3]. We validate the model and show its feasibility in a decomposition-type inverse scheme with synthetic measurement data [4], figure 1, as well as in the inversion of experimental scatterometric data [4], figure 2. Finally, we use a related forward model in the inversion of synthetic measurement data to estimate aperiodic defects in a nanograting [5], figure 3.

Optimal reliability allocation for large software projects through soft computing techniques

Software architecture is considered as a critical design methodology for the development of complex software. As an important step in software quality assurance, the optimal reliability allocation for software projects can be obtained by minimizing the total cost of achieving the target reliability or maximizing the system reliability subject to budget constraints.
These kinds of optimization problems were considered both in deterministic and stochastic frameworks in literature. Recently, the intuitionistic-fuzzy optimization approach was considered as a soft computing successful modelling approach. Firstly, a review on existing soft computing approaches to optimization is given. The main section extends the results considering self-organizing migrating algorithms for solving intuitionistic-fuzzy optimization problems attached to complex fault-tolerant software architectures which proved to be convergent with better or similar results (in speed) as genetic or controlled Monte-Carlo approaches.

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Wind Turbine Control: Robust Model Based Approach
In the 1970s the oil price crisis encouraged investigation of non-petroleum energy sources of which wind energy was the most promising one. Lately global warming concerns have even intensified the demand for green and sustainable energy resources and opened up several lines of research in this area. Wind turbines are the most common wind energy conversion systems and are hoped to be able to compete economically with fossil fuel power plants in near future. However this demands better technology to reduce the price of electricity production. Control can play an essential part in this context. This is because, on the one hand, control methods can decrease the cost of energy by keeping the turbine close to its maximum efficiency. On the other hand, they can reduce structural fatigue and therefore increase the lifetime of the wind turbine.

The power produced by a wind turbine is proportional to the square of its rotor radius, therefore it seems reasonable to increase the size of the wind turbine in order to capture more power. However as the size increases, the mass of the blades increases by cube of the rotor size. This means in order to keep structural feasibility and mass of the whole structure reasonable, the ratio of mass to size should be reduced. This trend results in more flexible structures.

Control of the flexible structure of a wind turbine in a wind field with stochastic nature is very challenging. In this thesis we are examining a number of robust model based methods for wind turbine control. Firstly we examine potentials of synthesis methods and use -tools to analyze robustness of the resulting controllers both in terms of robust stability and robust performance. Afterwards we employ model predictive control (MPC) and show that the way MPC solves control problems suits wind turbine control problems very well, especially when we have preview measurements of wind speed using LIDARs. For the control problem with LIDAR measurements we have proposed a new MPC approach which gives better results than linear MPC while it has almost the same computational complexity. We have also tackled wind turbine control using robust MPC. In general, robust MPC problems are very computationally demanding, however we have shown that with some approximations the resulting robust MPC problem can be specialized with reduced computational complexity.

After a short introduction on wind energy and wind turbines in chapter 1, we briefly explain wind turbine modeling in chapter 2. Introductions to different control design methods are given in chapter 3. The goal of this chapter is to show how different control methods are chosen. The next eight chapters comprise the body of the thesis and are scientific papers that are published or going to be published. Control methods which were briefly introduced in chapter 3 are explained in these chapters in details.

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NNNSYSID 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 (NNNSYSID) and the neural network based control system design toolkit (NNCTRL). The NNNSYSID 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 NNNSYSID 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 NNNSYSID and NNCTRL.