Monday 16:30-18:00

A quadratic programming-based method for quantized system identication
Xian'en Liu, Jiandong Wang and Qinghua Zhang (INRIA Rennes)

This paper proposes a quadratic programming (QP)-based method, for linear dynamic system identification from quantized data or binary measurements. The main idea of the proposed method is to reformulate the identification problem for finite impulse (FIR) systems, usually viewed as a nonlinear estimation problem with discontinuous nonlinearities, in the form of a standard QP problem, which is a convex optimization problem and can be solved efficiently. The QP-based method is equally applicable to both quantized data and binary measurements without any modification. It has no special assumptions on the identification experiments. An iterative QP-based method is also developed for the identification of infinite impulse response (IIR) systems. Numerical examples demonstrate the effectiveness of the proposed method.

A comparison of closed-loop subspace identification methods
Gijs van der Veen, Jan-Willem van Wingerden, Michel Verhaegen (TUD)

Identification of crystallization systems: open challenges
Marco Forgione (TUD)

Crystallization from solution is a well-known purification and separation unit operation of interest in different industrial sectors. Batch cooling crystallization, in particular, is often applied as a purification step in the pharmaceutical industry, characterized by relatively low-volume and high-value products.
Crystallization, as others disperse particulate processes, is usually described by means of the so-called Population Balance Equation (PBE), a partial differential equation describing the distribution of discrete particles (the crystals) in the continous phase (the liquid solution).
Modeling and identification of crystallization is hindered by the scarce first principle understanding about some basic phenomena occurring in crystallization such as crystal growth and nucleation, for which different rival models appeared in literature.
Due to this lack of exact knowledge, the PBE describing the process contains a number of both structural and parametric uncertainties. Furthermore, the accuracy of measurements is severely limited in practice for this kind of processes. An oculate design of the identification experiments is likely to give substantial improvements both in the selection of the most appropriate model structure and the estimation of the parameters.

Determining the direction of signal flow in open and closed loop systems based on signal measurements
Arne Dankers (TUD)

Identification of systems with localized nonlinearity: from state-space to block-structured models

Anne Van Mulders, Laurent Vanbeylen, Johan Schoukens (VUB)

The goal of this work is to join the benefits of block-structured models with those of nonlinear state-space models. In general, a block-structure is more sparse and yields extra physical insight, while nonlinear state-space models are very flexible (with a high number of parameters and nearly no insight). In order to maximally preserve the flexibility of the state-space model, the considered block-structure entails several simpler structures. The chosen structure can e.g. describe Wiener, Hammerstein, Wiener-Hammerstein and nonlinear feedback structures. The static nonlinearity is assumed to be polynomial. In fact, the chosen block-structure is the most general discrete-time representation of a system with one, SISO, polynomial, static nonlinearity. The approach is to first distill the static nonlinearity out of a more general polynomial state-space model. Next, a MIMO linear dynamic part can easily be identified, yielding extra structural insight.

On the use of multisine excitation for a piezoelectric tactile sensor system for tissue differentiation

D. Oliva Uribe, J. Schoukens and J. Wallaschek (VUB)

Resection of brain tumors is a very difficult task. Even though the information provided by imaging systems like MRI is enough to conduct successfully this surgical procedure, a brain shift occurs when the skull is opened leading to the lost of the exact position of the tumor. At this point a neurosurgeon has to decide what and where to cut based only on visual and tactile impressions. In consequence, the availability of a tactile sensor with higher sensitivity than human senses, could improve the quality of this crucial surgical procedure. We have developed a tactile sensor using a piezoelectric bimorph for brain tissue differentiation. The proposed sensor system relies on the evaluation of the frequency response function to identify changes in the mechanical conditions when the sensor is in contact with brain tissue. First experiments carried out on tissue gelatin phantoms with slightly differences in their mechanical properties, showed that is possible to detect even minimal differences but the measurement time was considerable long (approximately 2 mins) using standard frequency sweep response. In order to have a reliable instrument that can be used in surgical procedures, it is necessary to enhance the capabilities of the tactile sensor system. The present work reports our last efforts to improve the measurement procedure using multisine excitation and its comparison with standard frequency sweep response. Time and accuracy using multisine excitation are improved radically. In addition, further steps to provide the sensor system with the function to characterize the mechanical properties by the estimation of viscoelastic parameters using system identification techniques are presented.

Non-parametric Identification of Weakly Nonlinear Periodically Time-varying Systems
Ebrahim Louarroudi, Rik Pintelon and John Lataire (VUB)

Although the identification framework of linear time-invariant (LTI) systems covers a vast number of applications, there exist still circumstances where the linear and time-invariant conditions are not fulfilled. Time-varying systems, in particular Periodically Time-Varying (PTV), could be found in a lot of engineering applications such as biochemical processes, mechanical system, electronic circuits etc.. In this poster multisine excitations (periodic signals) are applied to a PTV system; since this kind of excitation signals allows us to discriminate between the noise and the nonlinear distortion from a single experiment. We start with the class of systems having a linear PTV behavior, which can be arbitrarily well approximated under mild conditions by a parallel structure consisting of a finite number of weighted LTI systems, the so-called Harmonic Transfer Functions (HTF). Making use of a polynomial approximation of the HTFs in the frequency domain, the evolution of the time-varying dynamics, described by the concept of the instantaneous transfer function (ITF), is then estimated in an output-error framework and this from only one single experiment. Afterwards we extend the methodology to PTV systems with a weakly nonlinear behavior. This can be done through the replacement of the HTFs by the Best Linear Approximation (BLA) of the HTFs plus an additional disturbance source ys(t), called the stochastic nonlinear distortion, that captures the nonlinearities. Moreover, non-linear distortion levels and the noise floor are provided as well. The developed non-parametric estimator is demonstrated on a real-life weakly nonlinear periodically time-varying device under test (an electronic circuit).

A class of broad band excitation designed and applied for nonlinear system identification: A wet-clutch application
W.D. Widanage and J. Schoukens (VUB)

The poster presents a range of broadband signals and their advantages for nonlinear identification. They belong to the class of signals called multisine signals and offer great design flexibility, such as the frequency content, signal amplitude levels or the amplitude distribution. Depending on the particular nonlinear application these attributes can be effectively designed to drive the system into a dynamic region of interest while maintaining within any operating constraints. Three signals designs are illustrated which are the *random phased multisine*, *positively skewed multisine* and *crest factor optimised multisine*. Further when measuring for identification, the signals can be combined with a nominal control signal of the system to enrich and model its finer dynamics. All these signals were made use of to effectively identify the pressure dynamics of a wet-clutch system.

Comparison of some efficient black- and grey-box nonlinear model structures
Laurent Vanbeylen (VUB)

In nonlinear system identification, it is well-known that the richness of the model class determines the model's performance on real-life data. The model description should therefore capture the most common forms of nonlinear effects, such as nonlinear feedback. In this poster, different, sometimes barely studied, black- and grey-box candidate nonlinear dynamic model structures will be presented, comparing the flexibility, the parameter-parsimony, the physical insight and the open identification challenges. Both state-space and block-structured representations will be highlighted.

Under modeling and Border effect of Local Polynomial method
Griet Monteyne, Diana Ugryumova and Gerd Vandersteen (VUB)

A non-parametric system identification method, the Local Polynomial (LP) method, was recently developed to remove the leakage errors, determine a non-parametric model of the linear part of the system, and estimate the covariance matrix of the additive noise. The transient response in time domain translates to leakage in the frequency domain, which causes errors in the frequency response function (FRF) estimation. The LP method assumes that the transient and the FRF are smooth functions of frequency, while the excitation is assumed to be a rough function of the frequency (e.g. random noise or random phase multisine). This enables the separation of the transient and the FRF by locally approximating both by a polynomial function of the frequencies. In this way, a significant part of the leakage can be removed. At the same time, interpolation errors are introduced by both the transient and the FRF polynomials. The interpolation errors are significant where the transient and/or FRF fluctuate fast, and hence demand a high order polynomial approximation. The order of the polynomial and the considered frequency interval, on which the polynomials are estimated, are controlled by the user. In most cases, this frequency interval can be chosen symmetrically around the frequency line at which the transient and/or FRF are estimated. At the borders, e.g. around DC, there are not enough frequency lines available, and hence the frequency interval becomes asymmetric.
This poster discusses the non-parametric FRF estimate obtained using the LP method. The focus is put on the increase of the estimated variance of the FRF estimate at the border. This increase is caused by the under modeling of the transient/FRF at the border. The estimated variance does not only contain the true variance but also a bias error due to under modeling. This bias error, and thus the estimated variance, can be decreased by increasing the order of the polynomial estimate. Another solution exists in decreasing the amount of frequency lines used for the estimation of the polynomial. However, the amount of frequency lines always needs to be at least as large as the amount of parameters for the polynomial estimate. That is why we propose to use all the frequency lines (excited as well as non-excited) and estimate the FRF and transient at the same time. In this way the total amount of frequency lines remains large enough for estimating the parameters while the amount of excited frequency lines decreases. That is why the bias of the FRF estimate vanishes and thus the estimated variance decreases at the border in the latter case. The variance increases slightly at all the frequency lines. This increase in variability is, however, negligible compared to the decrease of the bias at the border. A simple simulated SISO system with added white noise is used to illustrate this problem.

On Optimal Input Design for Model Predictive Control
Marietta Annergren and Christian Larsson (KTH)

We consider a method for optimal input design in system identification for control. The approach addresses model predictive control (MPC). The objective of the framework is to provide the user with a model which guarantees that a specified control performance is achieved, with a given probability. We see that, even though the system is nonlinear, using linear theory in the input design can reduce the experimental effort. The method is illustrated in a minimum power input signal design in system identification of a water tank system.
This is joint work with Håkan Hjalmarsson

MOOSE: Model based optimal input signal design toolbox for Matlab
Marietta Annergren and Christian Larsson (KTH)

We present version 1.0 of a model based optimal input design toolbox for Matlab. The goal of the toolbox is to simplify the implementation of optimal input design problems. The main focus is on minimizing experimental cost while guaranteeing some application constraints for the identified model. The toolbox also includes support for classical input design formulations such as d-optimal design.

The use of System Identification in Model Based Engine Control
Oscar Flärdh and Jonas Mårtensson (KTH)

This poster presents two applications of system identification for model based control of the airpath of an SI engine. In the first application, a static model for the air flow through the inlet valves is presented together with a model for the amount of air that is trapped in the cylinders during the combustion. The effects of different valve timings are captured and the models are also used for predictions of the engine torque.
The second application is a dynamic nonlinear model for how the exhaust pressure depends on the turbo actuation and the air flow. The model is identified in two steps, first finding a static nonlinear relation from steady-state data and then identifying a linear dynamic model from transient data.
The models are validated using measurement data from an engine test bench. Both models are useful for control of the transient torque response, using simultaneous turbo and valve timing actuations.

Distributed parametric and nonparametric regression with on-line performance bounds computation
Damiano Varagnolo (UNIPD)

We focus on collaborative wireless sensor networks, where agents are randomly distributed over a region of interest and collaborate to achieve a common estimation goal. In particular, we introduce two consensus-based distributed linear estimators. The first one is designed for a Bayesian scenario, where an unknown common finite-dimensional parameter vector has to be reconstructed, while the second one regards the nonparametric reconstruction of an unknown function sampled at different locations by the sensors. Both of the algorithms are characterized in terms of the trade-off between estimation performance, communication, computation and memory complexity. In the finite-dimensional setting, we derive mild sufficient conditions which ensure that distributed estimator performs better than the local optimal ones in terms of estimation error variance. In the nonparametric setting, we introduce an on-line algorithm that allows the agents both to compute the function estimate with small computational, communication and data storage efforts, and to quantify its distance from the centralized estimate given by a Regularization Network, one of the most powerful regularized kernel methods. These results are obtained by deriving bounds on the estimation error that provide insights on how the uncertainty inherent in a sensor network, such as imperfect knowledge on the number of agents and the measurement models used by the sensors, can degrade the performance of the estimation process. Numerical experiments are included to support the theoretical findings.

A non-degenerate Rao-Blackwellised particle filter for estimating static parameters in dynamical models
F. Lindsten, T. B. Schön and L. Svensson

The particle filter (PF) has emerged as a powerful tool for solving nonlinear and/or non-Gaussian filtering problems. When some of the states enter the model linearly, this can be exploited by using particles only for the "nonlinear" states and employing conditional Kalman filters for the "linear" states; this leads to the Rao-Blackwellised particle filter (RBPF). However, it is well known that the PF fails when the state of the model contains some static parameter. This is true also for the RBPF, even if the static states are marginalised analytically with a Kalman filter. The reason is that the moments of the linear states are computed conditioned on nonlinear particle trajectories, which are bound to degenerate over time. To circumvent this problem, we propose a method for targeting the filtering density for the linear state, conditioned on just the "current" nonlinear state. This results in an RBPF-like method, capable of estimating static states in nonlinear dynamical models. As a possible application, we consider recursive, Bayesian parameter estimation.

Tuesday 10:30-12:00

Structured Model Order Reduction
Christopher Sturk (KTH)

This talk will deal with model order reduction of interconnected linear systems. The objective is to reduce the subsystems while retaining the interconnection structure. Two different approaches will be presented, one heuristic which tries to capture the effects of the interconnection while reducing the order of the subsystems and one method based on LMIs which comes with error bounds. The latter method is not always applicable, but it will be shown that it is in fact applicable to interconnection structures consisting of cascaded stable systems and negative feedback loops of strictly positive real systems. Model reduction of a boiler-header system and of power systems is shown to illustrate the theory.
This is joint work with Henrik Sandberg.

A Least Squares Approach to Direct Frequency Response Estimation
Per Hägg (KTH)

Traditionally, the frequency response function has been estimated directly by dividing the discrete Fourier transforms of the output and the input of the system. This approach suffers from leakage errors and noise sensitivity. Lately these errors have been studied in detail. The main observation is that the error has a smooth frequency characteristic that is highly structured. The recently proposed local polynomial method uses this smoothness, and tries to estimate the frequency response function along with a smooth approximation of the error term. Here we propose a method, closely related to the local polynomial method, but instead of using the smoothness of the error we explore the structure even further. The proposed approach to estimate the frequency response function seems promising, as illustrated by simulations and comparison with current state of the art methods.
This is joint work with Håkan Hjalmarsson and Bo Wahlberg

Chance Constrained Input Design
Dimitrios Katselis (KTH)

The following problem is studied: design an input signal with the property that the model estimated using it satisfies a given performance level with a prescribed probability. This problem is mathematically translated into a chance constraint optimization problem, which is typically non convex. To solve it, several convex approximations are proposed and compared.

On Identification-Related Uncertainty Structures
Tom Oomen (Eindhoven University of Technology)

The performance of multivariable robust controllers highly depends on the considered model set. The aim of this poster is to analyze identification-related model uncertainty structures. We present a new coprime-factor based uncertainty structure and experimentally compare the results to existing uncertainty structures on a multivariable automotive application. The results confirm that the new uncertainty structure provides an improved connection between identification and the control objective. In addition, the new results are especially important for multivariable systems, since these take both frequency scaling and the scaling of the different model uncertainty channels into account.

Automatic ARIMA Model Identification and Prediction of Specimen Drift in Experimental STEM Image Sequences.
Pauline Vos (TUD)

For the automation of transmission electron microscopes (TEMs) a scheme is required to compensate specimen drift. In this pilot study the toolbox ARMASA was used to identify ARIMA models for finite experimental drift sequences estimated from images recorded with a scanning TEM (STEM). The models were then used to compare different methods for one prediction, using the prediction error variance as a performance metric.

One-step Identification of Parallel Hammerstein Systems
M. Schoukens, G. Vandersteen, Y. Rolain (VUB)

Hammerstein systems consist of a static nonlinearity connected in tandem to a linear time invariant (LTI) system. These systems are used to model nonlinear systems for which the nonlinearity is present mainly at the input such as power amplifiers, chemical processes and physiological systems. In some systems, different signal paths are present, each with different nonlinearities and different dynamics. Or some systems have a dynamical behavior depending on the applied input power. In those cases a Hammerstein model suffers from a lack of general applicability. Such systems can be better modeled by replacing the single Hammerstein model by a more general structure consisting of a parallel connection of Hammerstein systems.

Parameter reduction of a Wiener model using the best linear approximation

Koen Tiels and Johan Schoukens (VUB)

A Wiener model can describe a large class of nonlinear systems. The dynamics of the system are modeled by a set of orthonormal basis functions, while the nonlinearity is modeled by a multivariate polynomial. Often, this polynomial contains a lot of terms. In this work we propose to replace one of the basis functions by the best linear approximation of he system. In this way the number of relevantly contributing terms in the multivariate polynomial is reduced. Simulation results on a Wiener system show a major reduction of the number of parameters, while the rms error on the simulated output is still reasonable.

Choice of binary excitation signals in nonlinear system identification

Roland, H. K. Wong (VUB)

In nonlinear system identification, a robust method involves averaging across multiple independent realizations of experiments, in order to extract the best linear approximation of the said system. The choice of signal in systems which take only binary inputs is much more restricted. Time required to perform experiments is nearly always the limiting factor to obtaining satisfactory results. This poster illustrates the advantages of using m-sequences over Gaussian based random binary noise in reducing experiment time and also answers the question whether the use of lowly correlated sequences will improve the estimate by decreasing nonlinear noise further.

On the use of Neural Networks and Support Vector Machines for the identification of nonlinear state space models

Anna Marconato[1], Jonas Sjoberg[2], Johan Schoukens[1]

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This poster discusses the application of regression methods from the machine learning community to the identification of nonlinear state space models. In this approach, linear modeling techniques are used to capture system dynamics, and the remaining nonlinear terms are identified separately. This combines the best of two worlds. On one hand the linear identification theory is very well suited to model dynamic systems, while on the other hand the methods from the machine learning community are very powerful tools to model multidimensional static nonlinear functions. By combining these two methodologies, an approximated static version of the problem is solved, so that one does not have to deal with the recursion in the state equation.
A two step initialization procedure is proposed. First the dynamics of the system are modeled with the Best Linear Approximation, resulting in a linear state space model, then a simplified problem is obtained by estimating the nonlinear states. This can be done by solving a Least Squares problem or, alternatively, by means of Kalman filtering.
Several possibilities can then be considered to estimate the nonlinearities in the model. This work focuses on the use of Neural Networks and Support Vector Machines as regression tools, and analyses advantages and drawbacks of the two methods.
Finally, all parameters of the initialized nonlinear model are optimized, e.g. by means of a Levenberg-Marquardt algorithm.

Frequency Domain Errors-In-Variables Identification of a Time-Varying, Discrete Time System

John Lataire and Rik Pintelon (VUB)

This poster discusses the parametric identification of single-input single-output, linear, discrete-time, time-varying systems. The model equation is a linear ordinary difference equation with polynomial coefficients that vary in time. The model equation is formulated exactly in the frequency domain. Based on this equation a consistent estimator is constructed within an errors-in-variables framework. The estimator is illustrated on a simulation example.

Improved real-time aerodynamic model parameter identification

Roger Larsson, Martin Enqvist (ULIN)

Online real-time estimation of aerodynamic characteristics during flight tests is useful for surveying the amount of excitation in the collected data. Here an improved version of a real-time frequency domain method is described. The improvements involve correction terms in order to compensate for undesirable leakage effects when the Fourier transform is computed and the use of the instrumental variables method in order to handle noisy data. Different maneuvers and turbulence settings have been used in simulations to test the method. So far the results of the simulations look promising. If the simulation tests are successful the algorithm will be implemented in the real flight test environment at Saab.

The disappearance of nonlinearities in model residuals for high sampling rates

Jésica Escobar, Martin Enqvist (ULIN)

Here we deal with the choice of the sampling rate in nonlinear system identification applications. In particular, we focus on the effect of the sampling rate when the prediction-error method is used. On one hand, a high sampling rate is advantageous since it enables the measurement of high-frequent nonlinear components in the output signal of the system. However, a high sampling rate might also make it harder to detect that the system is nonlinear, since the nonlinearities seem to disappear in the residuals from a linear model in some cases. A numerical example illustrates this phenomenon.

Comparison of modeling techniques for outphasing radio frequency power amplifiers.

Ylva Jung (ULIN)

A digital radio frequency power amplifier is more power efficient than an analog amplifier, but may cause interference in adjacent transmitting channels. This interference can be reduced by the use of a predistorter (a digital prefilter). An ideal predistorter should invert the inherent nonlinearities in the amplifier, and thus a model of the amplifier is needed. Two modeling approaches have been evaluated. One is to solve a nonconvex optimization problem and leads to very good results. The second approach is to rewrite the problem as a least squares problem, but this leads to a less accurate model. The predistorter can also be produced in multiple ways, using a nonconvex optimization, a least squares reformulation or an analytical inverse.

Kernel Selection in Linear System Identification: a Classical Perspective.
Tianshi Chen, Henrik Ohlsson and Lennart Ljung (ULIN)

In this contribution, the choice of kernels for estimating the impulse response of linear stable systems is considered from a classical, “frequentist”, point of view. The kernel determines the regularization matrix in a regularized least squares estimate of an FIR model. The quality is assessed from a mean square error (MSE) perspective, and measures and algorithms for optimizing the MSE are discussed. The ideas are tested on the same data bank as used in one of Pillonetto et' al's paper. The resulting findings and conclusions in the two papers are very similar despite the different perspectives.

Bias correction for polynomially structured low rank approximation problems
Ivan Mrakovsky (UCAM)

At the 2010 ERNSI meeting, I presented an approach for geometric fitting of algebraic curves to data that reduces the original fitting problem to the abstract problem of polynomially structured low-rank approximation. The geometric fit, however, yields a biased estimator in the errors-in-variables setting. In addition, the problem is nonconvex and the solution methods require initial approximation and are susceptible to local minima.
The new results presented at the 2011 meeting are about a bias correction that results in a computationally simpler algorithm. The key elements of the correction procedure are the use of Hermite polynomials and the solution of a polynomial eigenvalue problem that yields the estimates of the noise variance and the model parameters at the same time.