ERNSI 2019 WORKSHOP

KASTEEL VAESHARTELT MAASTRICHT, THE NETHERLANDS, SEPTEMBER 22-25, 2019

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PROGRAM

28th ERNSI Workshop in System Identification is organized with the support of:

SUNDAY SEPTEMBER 22, 2019

From 14.00	Arrival and check in	
16.00	Coffee and cake ‘Limburse vlaai’	*Location: Fumoir*
19.00	Welcome dinner	*Location: Klassieke zalen*

MONDAY SEPTEMBER 23, 2019

07.00 – 08.50	*Breakfast*	*Location: Restaurant*
08.50 – 09.00	Welcome	*Location: Room 10, 11, and 12*
09.00 – 10.00	Plenary talk 1	**Rose Yu (US)** Deep learning for spatiotemporal data
10.00 – 10.30	*Tea/coffee break*	
10.30 – 11.00	Regular talk 1	**Roy Smith (CH)** Stochastic processes: Stability and identification
11.00 – 11.30	Regular talk 2	**Ivan Markovsky (BE)** Data-driven structured noise filtering via common dynamics estimation
11.30 – 12.00	Regular talk 3	**Tomas McKelvey (SE)** On recent advances in rank constrained optimization with applications to subspace based estimation methods
12.00 – 12.30	Discussion	
12.30 – 14.00	*Lunch*	*Location: Restaurant* *Location: Klassieke zalen (team leaders)*
14.00 – 15.00	Plenary talk 2	**Michael Eichler (NL)** Causal Inference from Multivariate Time Series: Principles and Problems
15.00 – 15.30	*Tea /coffee break*	
15.30 – 16.15	Tutorial 1	**Arun Venkitaraman (SE)** Graph Signal Processing and Machine Learning
16.15 – 16.45	Regular talk 4	**Manfred Deistler (AUS)** On the sensitivity of Granger causality to errors-in-variables, linear transformations and subsampling
16.45 – 17.15	Regular talk 5	**Xiaodong Cheng (NL)** Allocation of Excitation Signals for Generic Identifiability of Linear Dynamic Networks
17.15	*Power snack*	
17.15 – 18.45	Poster session 1	*Location: Room 1*
19.30	*Dinner*	*Location: Restaurant*

TUESDAY SEPTEMBER 24, 2019

07.00 – 09.00	*Breakfast*	*Location: Restaurant*
09.00 – 10.00	Plenary talk 3	*Location: Room 10, 11, and 12* **Donatello Materassi (US)** Network recovery and identification via graphical separation tests
10.00 – 10.30	*Tea/coffee break*	
10.30 – 11.00	Regular talk 6	**Tom Oomen (NL)** Numerically optimal identification of complex systems
11.00 – 12.30	Poster session 2	*Location: Room 1*
12.30 – 14.00	*Lunch*	*Location: Restaurant*

		Social-cultural program
14.30	Travel	Departure by bus to location
15.00 - 17.00	Guided tour	Tour through the Hoge fronten and Kazematten in Maastricht. Starting point: Bastion Holsteyn, Statensingel 14, Maastricht *Note: walking shoes required. Temperature will be 13 degrees, so bring sufficient clothing.*
17.00 – 19.00	Drinks, talk and tour	**Theater aan het Vrijthof** Vrijthof 47, Maastricht Welcome drinks and snacks 18.00: Lecture about the origination of the theater on this historic site in Maastricht, including a backstage tour.
19.00 - 22.00	Dinner	**De Groote Societeit** Vrijthof 36, Maastricht
22.15	Travel	Departure by bus to Vaeshartelt

WEDNESDAY SEPTEMBER 25, 2019

07.30 – 09.00	*Breakfast*	*Location: Restaurant*
09.00 – 09.45	Tutorial 2	*Location: Room 10, 11, and 12* **Johan Karlsson (SE)** Optimal mass transport for tracking, estimation, and information fusion
09.45 – 10.15	Regular talk 7	**Kévin Colin (FR)** Data informativity for the open-loop identification of MIMO systems in the Prediction Error framework
10.15 – 10.45	*Tea/coffee break*	
10.45 – 11.15	Regular talk 8	**Michael Döhler (FR)** The local approach for vibration-based damage diagnosis of civil structures
11.15 – 11.45	Regular talk 9	**Luca Zancato and Alessandro Chiuso (IT)** SGD tunneling through barrier potential exploiting the Loss Landscape of Neural Nets
11.45 – 12.15	Regular talk 10	**Valentina Breschi and Simone Formetin (IT)** Direct data-driven design of switching controllers
12.15 – 12.30	Discussion	
12.30 – 14.00	*Lunch*	*Location: Restaurant*
14.00	Departure	

PLENARY TALKS

PL1 Rose Yu (US)

Affiliation: Khoury College of Computer Sciences, Northeastern University

Title: Deep Learning For Spatiotemporal Data

Abstract: Applications such as climate science, intelligent transportation, aerospace control, and sports analytics apply machine learning for large-scale spatiotemporal data. This data is often nonlinear, high-dimensional, and demonstrates complex spatial and temporal correlations. Existing deep learning models cannot handle complex spatiotemporal dependency structures. We'll explain how to design deep learning models to learn from large-scale spatiotemporal data, especially for dealing with non-Euclidean geometry, long-term dependencies, and logical and physical constraints. We'll showcase the application of these models to problems such as long-term forecasting for transportation, long-range trajectories synthesis for sports analytics, and combating ground effect in quadcopter landing for aerospace control.

PL2 Michael Eichler (NL)

Affiliation: University of Maastricht

Title: Causal Inference from Multivariate Time Series: Principles and Problems

Abstract: In time series analysis, inference about cause-effect relationships among multiple time series is commonly based on the concept of Granger causality, which exploits temporal structure to achieve causal ordering of dependent variables. One major and well known problem in the application of Granger causality for the identification of causal relationships is the possible presence of latent variables that affect the measured components and thus lead to so-called spurious causalities. This raises the question about whether Granger causality is an appropriate tool for causal learning; indeed, there are many researchers that deny any such claim.

To answer the question in more depth, we present a graph-theoretic approach for describing and analysing Granger-causal relationships in multivariate time series that are possibly affected by latent variables. It is based on mixed graphs in which directed edges represent direct influences among the variables while dashed edges - directed or undirected - indicate associations that are induced by latent variables. We show how such representations can be used for inductive causal learning from time series and discuss the underlying assumptions and their implications for causal learning. Finally we will discuss non-Markovian constraints imposed by latent variable structures and how these can be exploited for causal inference.

PL3 Donatello Materassi (US)

Affiliation: University of Minnesota, Twin Cities

Title: Network recovery and identification via graphical separation tests

Abstract: Networks have become ubiquitous in science. The principal advantages provided by a networked system are a modular approach to design, the possibility of directly introducing redundancy and the realization of distributed and parallel algorithms. All these advantages have led to consider networked systems in the realization of many technological devices. At the same time, it is not surprising that natural and biological systems tend to exhibit strong modularity, as well.
Interconnected systems are successfully exploited to perform novel modeling approaches in many fields, such as Economics, Biology, Cognitive Sciences, Ecology and Geology.
While networks of dynamical systems have been deeply studied and analyzed in physics and engineering, there is a reduced number of results addressing the problem of recovering and identifying an unknown network of dynamic systems, since it poses formidable theoretical and practical challenges. One of the main challenges is the identification of networked systems that are difficult to access or manipulate. Thus, the necessity for general tools for the identification of networks that are known only via non-invasive observations is rapidly emerging.
The talk addresses this problem leveraging approaches from the theory of graphical models and showing under what conditions they can be extended to networks of dynamic systems.

REGULAR TALKS

R1 Roy Smith (CH)

Affiliation: Swiss Federal Institute of Technology (ETH)

Title: Stochastic processes: Stability and identification

Abstract: We use a simple example to illustrate that systems with stochastic feedback gains can give rise to a rich and unexpected range of behaviours. A variety of notions of stability and be considered: median, mean, and variance stability are considered. For scalar for scalar discrete-time systems (with almost arbitrary distributions), necessary and sufficient conditions for these types of stability are presented. The conditions differ for each type of stability. For example, it is possible to create a stochastic feedback system in which the median of the state goes to zero, but the mean evolves to infinity. We show that it is easy to estimate the median o these stochastic systems from experimental data. Estimation of the mean however can be rather more difficult. The non-intuitive behaviour and identification difficulties arise because the state variable in such systems evolves towards a heavy-tailed distribution and exhibits some non-intuitive characteristics. For example, one can use stochastic feedback to stabilise unstable systems where one does not even know the sign of the unstable pole or the sign of the system gain. A more dramatic example is an investment scheme which simultaneously yields unbounded expected profit and almost certain bankruptcy to every investor.

R2 Ivan Markovsky (BE)

Authors: Ivan Markovsky (ELEC), Tianxiang Liu (RIKEN Center, Tokyo), and Akiko Takeda (The University of Tokyo)

Title: Data-driven structured noise filtering via common dynamics estimation

Abstract: Classical signal from noise separation problems assume that the signal is a trajectory of a low-complexity linear time-invariant system and the noise is a random process. We generalize this classical setup to what we call data-driven structured noise filtering. In the new setup, the noise has two components: structured noise, which is also a trajectory of a low-complexity linear time-invariant system and unstructured noise, which is a zero-mean white Gaussian process. The key assumption that makes the separation problem in the new setup well posed is that among several experiments the signal's dynamics remains the same while the structured noise's dynamics varies. The data-driven structured noise filtering problem becomes then a problem of estimation of common linear time-invariant dynamics among several observed signals. We show that this latter problem is a structured low-rank approximation problem with multiple rank constraints and use local optimization as well as subspace methods for solving it.

R3 Tomas McKelvey (SE)

Affiliation: Chalmers

Title: On recent advances in rank constrained optimization with applications to subspace based estimation methods

Abstract: Many estimation problems has som sparsity constraints, often related to a model order choice. In this talk we will discuss some canonical estimation problem where sparse solutions are

desired. In general the original sparse problem formulation is not a convex problem. Here we review how an approximation based on the convex envelope yields a convex problem which can be easily solved by standard iterative methods like ADMM. We discuss the sparse vector estimation problem (LASSO), group LASSO and the sparse vector case for complex valued problems. Matrix approximation problems involving both structure and rank constraints is yet another class of sparse estimation problems that are found in subspace methods. Here we compare the nuclear norm approximation with a more recent technique based on the convex envelop of a loss function including both the matrix approximation term and the rank constraint. We illustrate the performance of the various techniques through the classical line spectral estimation problem.

R4 Manfred Deistler (AUS)

Affiliation: TU Wien

Title: On the sensitivity of Granger causality to errors-in-variables, linear transformations and subsampling

Abstract: This paper studies the sensitivity of Granger causality to the addition of noise, the introduction of subsampling, and the application of causal invertible filters to weakly stationary processes. Using canonical spectral factors and Wold decompositions, we give general conditions under which additive noise or filtering distorts Granger-causal properties by inducing (spurious) Granger causality, as well as conditions under which it does not. For the errors-in-variables case, we give a continuity result, which implies that: a "small" noise-to-signal ratio entails "small" distortions in Granger causality. On filtering, we give general necessary and sufficient conditions under which "spurious" causal relations between (vector) time series are not induced by linear transformations of the variables involved. This also yields transformations (or filters) which can eliminate Granger causality from one vector to another one. In a number of cases, we clarify results in the existing literature, with a number of calculations streamlining some existing approaches.

R5 Xiaodong Cheng (NL)

Affiliation: Eindhoven University of Technology, Control Systems group

Title: Allocation of Excitation Signals for Generic Identifiability of Linear Dynamic Networks

Abstract: A recent research direction in data-driven modeling is the identification of dynamic networks, in which measured vertex signals are interconnected by dynamic edges represented by casual linear transfer functions. Assuming that the topology of the underlying network is known, and all the vertex signals are measured, the major question addressed in this paper is where to allocate external excitation signals such that all the edges can be consistently estimated from measurement data. To tackle this synthesis problem, a novel graph structure, referred as directed pseudotree, is invented, and the generic identifiability of a directed network can be featured by a set of disjoint directed pseudotrees that cover all the parameterized edges of an extended network, which includes the correlation structure of process noises. Thereby, an algorithmic procedure is devised to decompose the extended network into a minimal number of disjoint pseudotrees, whose roots then provide potential locations for excitation signals. Furthermore, the proposed approach can be adapted using the notion of anti-pseudotrees to solve a dual problem, that is to select a minimal number of measurement signals for the generic identifiability of the overall network, under the assumption that all the vertices are excited.

R6 Tom Oomen (NL)

Affiliation: Eindhoven University of Technology, Control Systems Technology group

Title: Numerically optimal identification of complex systems

Abstract: System identification algorithms are typically implemented with finite precision arithmetic. The aim of this presentation is to investigate numerical aspects of frequency domain identification algorithms. It is shown how optimal numerical conditioning can be obtained through orthonormal polynomials with respect to a data-dependent discrete inner product. Extensions to instrumental variable identification and connections to the delta operator are presented. The resulting algorithms are illustrated on complex mechanical systems.

R7 Kévin Colin (FR)

Authors: Kévin Colin (Ecole Centrale de Lyon), Xavier Bombois (CNRS), Laurent Bako (Ecole Centrale de Lyon), Federico Morelli (Ecole Centrale de Lyon)

Title: Data informativity for the open-loop identification of MIMO systems in the Prediction Error framework

Abstract: In Prediction Error identification, to obtain a consistent estimate of the true system, it is crucial that the input excitation yields informative data with respect to the chosen model structure. We consider here the data informativity property for the identification of a Multiple-Input Multiple-Output system in open loop and we derive conditions to check whether a given input vector will yield informative data with respect to the chosen model structure. We do that for the classical model structures used in prediction-error identification and for the classical types of input vectors, i.e., input vectors whose elements are either multisines or filtered white noises.

R8 Michael Döhler (FR)

Affiliation: Inria

Title: The local approach for vibration-based damage diagnosis of civil structures

Authors: Michael Döhler, Laurent Mevel

Abstract: Monitoring the integrity of civil structures (such as bridges, buildings, wind turbines, etc.) can be achieved by observing small changes in a physical model, which are related to changes in the eigenvalues and eigenvectors of a linear dynamic system, based on vibration measurements. Since the external forces applied to a structure are usually unknown, the systems are stochastic. The monitoring of the changes in the state space properties of the underlying system can be done either by identification or change detection methods, which are dual. In this talk we present recent developments for vibration-based damage diagnosis within the framework of the asymptotic local approach to change detection. This approach allows the analysis of small changes in the dynamic properties of a system, based on the evaluation of a residual in which the properties of a reference state are confronted to measurements in the current state of a structure. This approach has been developed for instrumental variables and subspace-based residuals (Benveniste et al., 1987, Basseville et al., 2000). Its adaptation to the monitoring of large civil structures in operation requires a careful reconsideration of the underlying assumptions and methodology.
First, residuals are developed that are robust to possible changes in the unknown excitation conditions. Second, the uncertainty related to the reference data is taken into account in the

residual evaluation. Third, the link between the data-based residual and a physical model of a structure is established to isolate the physical parameters that are at the origin of the change, in order to perform damage localization and quantification, which is beyond data-driven change detection. The presented developments aim at robustness of the approach for real applications, which is demonstrated on several case studies using experimental data.

R9 Luca Zancato and Alessandro Chiuso (IT)

Affiliation: University of Padova

Title: SGD tunneling through barrier potential exploiting the Loss Landscape of Neural Nets

Abstract: Many authors have suggested studying the loss landscape of Deep Neural Networks (DNN) as a tool to understand their generalisation capabilities, the performance of optimisation algorithms as well as to tailor acceleration schemes. Nonetheless, a complete understanding of the entire learning process is still missing. This is mainly due to the complexity of the loss landscape, characterised by a rich structure with many local minima and saddle points.
In this context, the purpose of this paper is threefold: (i) understanding the stochastic nature of Stochastic Gradient Descent (SGD) and its link with the loss function; (ii) studying the loss landscape and the genesis of local minima by exploiting a simplified model; and (iii) suggesting a data sampling scheme for SGD which favours tunnelling through barriers thus possibly accelerating convergence speed. Experimental results with AlexNet and ResNet on CIFAR-10 are provided.

R10 Valentina Breschi and Simone Formetin (IT)

Affiliation: Politecnico di Milano

Title: Direct data-driven design of switching controllers

Abstract: Switching linear models can be used to represent the behavior of time-varying and nonlinear systems, while generally providing a satisfactory trade-off between accuracy and complexity. Although several control design techniques are available for such models, the effect of modeling errors on the closed-loop performance has not been formally evaluated yet. In this talk, an alternative data-driven synthesis scheme is then introduced to design optimal switching controllers directly from data, without needing a model of the plant. In particular, the theory will be developed for piecewise-affine controllers, which have proven to be effective in many real-world engineering applications. The performance of the proposed approach as compared to state-of-the-art switching controls and to other data-driven approaches is illustrated on some benchmark simulation case studies.

TUTORIALS

T1 Arun Venkitaraman (SE)

Affiliation: Division of Decision and Control Systems, KTH Royal Institute of Technology, Sweden

Title: Graph Signal Processing and Machine Learning

Abstract: The talk will first briefly review the emerging field of graph signal processing, where the basic concepts will be discussed.
Graph signal processing deals with development of mathematical tools for consistent analysis and processing of signals or data occurring over networks or graphs. The framework, by the way it is formulated, is directly applicable to a wide range of applications from sensor networks, biological, to traffic networks. The talk will also cover recent work on learning sparse graphs/connectivity matrices from graph signal data in a hyperparameter-free setting in the Sparse Iterative Covariance Estimation framework (SPICE). Finally, if time permits, some contributions concerning prediction of graph signals from inputs agnostic to a graph will be discussed.

T2 Johan Karlsson (SE) (based on joint work with Yongxin Chen, Filip Elvander, Isabel Haasler, Andreas Jakobsson, and Axel Ringh)

Affiliation: KTH Royal Institute of Technology

Title: Optimal mass transport for tracking, estimation, and information fusion

Abstract: The optimal mass transport problem is a classical problem in mathematics, and dates back to 1781 and work by G. Monge where he formulated an optimization problem for minimizing the cost of transporting soil for construction of forts and roads. Historically the optimal mass transport problem has been widely used in economics in, e.g., planning and logistics, and was at the heart of the 1975 Nobel Memorial Prize in Economic Sciences. In the last two decades there has been a rapid development of theory and methods for optimal mass transport and the ideas have attracted considerable attention in several economic and engineering fields. These developments have lead to a mature framework for optimal mass transport with computationally efficient algorithms that can be used to address problems in the areas of systems, control, and estimation. This talk will give an overview of the optimal mass transport framework and show how it can be applied to solve problems in state estimation, ensemble tracking, and information fusion. The approach is non-parameteric and can be applied to problems ranging from a small number of systems to a continuous flow of systems. A common obstacle in these applications is when only partial information is obtained, and we present generalizations of the Sinkhorn algorithm for this setting.

POSTERS

POSTER SESSION I

MONDAY SEPTEMBER 23, 2019

1 Andy Keymolen (BE)

Affiliation: Vrije Universiteit Brussel, departement ELEC

Title: Applying low frequency FOT in clinical practice by use of adaptive excitation signals

Abstract: Low frequency forced oscillation technique (FOT) (i.e. FOT below 5Hz) has high diagnostic potential for the detection of respiratory diseases but has not yet found its way into clinical practice. Due to the presence of the patient's breathing, patient-unfriendly measurement protocols are generally required to extract the necessary low frequency information on the patient's respiratory system.
This work presents a technique that allows for low frequency FOT measurements in the presence of spontaneous breathing. The use of adaptive excitation signals in combination with an external visual stimulus for breathing synchronization allows for the separation of breathing and FOT contributions in the measurement data. The method has been clinically tested on 63 patients and low frequency respiratory impedance measurements are gathered on healthy subjects, asthmatic patients and patients with chronic obstructive pulmonary disease (COPD).

2 Bob Vergauwen, Bart De Moor (BE)

Affiliation: KU Leuven

Title: Cayley-Hamilton theorem for sets of commuting matrices

Abstract: Multidimensional systems are systems characterised by signals who depend on several independent variables. These variables are for example time and space. In the past a couple of system realisations have been proposed, in this work the following system realisation is used

$$\begin{aligned} x[k_1+1,\ldots,k_n] &= A_1 x[k_1,\ldots,k_n] \\ &\vdots \\ x[k_1,\ldots,k_n+1] &= A_n x[k_1,\ldots,k_n] \\ u[k_1,\ldots,k_n] &= C x[k_1,\ldots,k_n]. \end{aligned}$$

The system matrices A_i must commute in order for the system to be well defined. Under this condition it can be shown that the output of the system is equal to,

$$y[k_1,\ldots,k_n] = CA_1^{k_1}\ldots A_n^{k_n}x[0,\ldots,0],$$

this equation is a direct generalisation of the output of a one dimensional discrete linear state space model where the output is equal to

$y[k] = CA^k x[0]$.Let $\chi(A) = \det(\lambda I - A) = \lambda^n + \alpha_1\lambda^{n-1} + \ldots + \alpha_{n-1}\lambda + \alpha_n = 0$

be the monic characteristic polynomial of the matrix A. Then the theorem of Cayley-Hamilton states that for every k the output satisfies the following difference equation

$y[k+n] + \alpha_1 y[k+n-1] + \ldots + \alpha_{n-1} y[k+1] + \alpha_n y[k] = 0$

This result is extended for the multidimensional system realisation and the question is asked: how can the difference equation be retrieved from a given state space realisation and is this difference equation unique. The presented results are based on an extension of the know theorem of Cayley-Hamilton.

3 Christof Vermeersch (BE)

Affiliation: KU Leuven

Title: Linear Multiparameter Eigenvalue Problems

Abstract: Much has been written about standard eigenvalue problems and their properties. However, linear multiparameter eigenvalue problems (linear MEPs) remain largely uncharted territory. Linear MEPs contain multiple eigenvalues and, therefore, extend the typical structure of the well-known standard eigenvalue problem:

$$(A_0 + A_1\lambda_1 + A_2\lambda_2 + \cdots + A_n\lambda_n)z = 0.$$

They emerge naturally in many physical applications, for example when solving partial differential equations via a separation of variables: Helmholtz, Laplace, and Schrödinger equations typically lead to linear MEPs. In systems and control, MEPs arise when identifying or reducing models of linear time-invariant systems.

Despite their fundamental linear algebra nature, the available literature about solving (linear) MEPs remains quite limited. Typically, numerical optimization methods are used to find (approximations of) the eigenvalues and -vectors. Algebraic approaches, on the other hand, confine themselves mostly to two-parameter eigenvalue problems.

We approach this problem from a different perspective and incorporate the linear MEP in the so-called block Macaulay matrix, which we iteratively extend until its null space has a special block multi-shift-invariant structure. Via a multidimensional realization problem in that null space, we obtain a standard eigenvalue problem that yields all the solutions of the original linear MEP.

4 Gaia Cavallo (BE)

Affiliation: Vrije Universiteit Brussel

Title: Accuracy of human joint impedance identification

Abstract: Human joint impedance represents the dynamical relationship between the torque and the angle of a joint of the human musculoskeletal system. The identification of human joint impedance of the lower limbs' joints can provide important information for the design and control of wearable bionic devices that can assist the user in performing daily tasks. However, there is only limited research on the identification of joint impedance during such tasks, where the joint impedance should be modeled by a time-varying system.

In this study, a consistent estimator is proposed for the identification of human joint impedance during locomotion. Human joint impedance is modeled as a mass-spring-damper system with time-varying parameters, which are represented as the sum of sigmoidal basis functions. A realistic ankle impedance simulation is obtained to perform a Monte Carlo analysis of the proposed estimator. The aim is to determine the required experimental conditions (persistency of excitation, measurement time/frequency resolution) to obtain a sufficiently low uncertainty for the application at hand. The results show that the proposed estimator can reconstruct the parameters of the system with high accuracy and low uncertainty for experimental conditions representative of human gait analysis.

5 Georgios Birpoutsoukis (BE)

Affiliation: UC Louvain – ICTEAM - Applied Mathematics

Title: Initial parameter estimation for Seasonal ARIMA models

Abstract: We identify time-series of energy consumption in order to develop predictive models and generate smart alerts. Monitoring the consumptions of electricity, gas, etc, is important to ensure the desired energy performance. Among other challenges, the estimated models should be able to capture the dominant characteristics of the underlying time-series processes such as the trend, the seasonality as well as the stochastic components of the process.
Seasonal Integrated Autoregressive Moving Average (SARIMA) models are considered towards this direction. Parameter estimation using this model structure and prediction error criteria often boils down to nonlinear non-convex optimization problems, which depend strongly on the choice of the initial values for the optimizing parameters. In this work, we propose a way to obtain good initial estimates for the model parameters by splitting the optimization problem into two, where parameters linked to different (seasonal or not) patterns in the process dynamics are estimated separately, without altering the SARIMA model structure.

6 Federico Morelli and Xavier Bombois (FR)

Affiliation: Laboratoire Ampère, Ecole Centrale de Lyon, Université de Lyon

Title: Resonance Frequency Tracking of a MEMS Resonator: Extremum Seeking vs System Identication

Abstract: In this work, we considered a MEMS resonator that must oscillate at its resonance frequency with a controlled amplitude. This behaviour is assured thanks to a closed loop control strategy ensuring that the resonator follows a given reference signal, which is a sine at a frequency equal to the resonance frequency. However, the resonance frequency of the resonator may change during the operation due to environmental factors i.e. temperature changes. Therefore, we want to track the changes in the resonance frequency of the resonator in order to adapt the reference signal accordingly. This challenge is usually tackled in the literature using an additional control scheme, such as Extremum Seeking, aiming at adapting the reference signal. However, a possible alternative would be to use system identication methods to estimate the resonance frequency using data collected during the operation of the resonator. In this poster, we therefore compare a classical tool used in literature to track the resonance frequency (i.e the Extremum Seeking control scheme), with alternatives based on System Identication.

7 Krishnan Srinivasarengan Vincent Laurain, Samir Aberkane (FR)

Affiliation: Université de Lorraine

Title: Modelling and leak detection in water distribution networks

Abstract: Water distribution networks (WDNs) form an integral part of the urban and rural infrastructure. The increasing awareness on the effects of climate change drives the water management companies to put stricter measures on water losses. In this poster, we present results on the development of a leak detection mechanism for a rural WDN in France, where the system identification techniques play a central role. The implicit assumption in the modelling step of machine learning is that `the training data consists only of healthy data'. However, the data series available for this project comes from WDN monitoring sensors that contain system faults (water leaks), and sensor faults. In this work, we show how to use such unhealthy data series to (i) efficiently model the system using machine learning approaches (Reproducing Kernel Hilbert Spaces - RKHS), (ii) To detect leaks or system faults and (iii) to separate system faults from the sensor faults by modelling the overall WDN as a graph, where the nodes represent the flow sensors which capture the downstream consumption pattern.

8 Pauline Kergus, Martine Olivi, Charles Poussot-Vassal, Fabrice Demourant (FR)

Affiliation: ONERA

Title: From reference model selection to controller validation: application to Loewner Data-Driven Control

Abstract: In [1] and [2], a new data-driven control technique based on frequency-domain data is proposed. It is a model reference technique. The identification problem is moved from the plant to the controller. Lately, the main focus has been put on the choice of the specifications and closed-loop stability analysis and/or enforcement, see [3]. Indeed, the choice of a reference model in data-driven control techniques is a critical step as it is pointed out in [4], [5] and [6]: it should represent the desired closed-loop performances and be achievable by the plant at the same time. In this work, we propose a method to build such a reference model, both reproducible by the system and having a desired behaviour. It is applicable to Linear Time-Invariant (LTI) monovariable systems and relies on the estimation of the plant's instabilities through a data-driven stability analysis technique. The L-DDC (Loewner Data Driven Control) algorithm is used to illustrate the impact of the choice of the reference model on the control design process. Finally, the proposed choice of specifications allows to use a controller validation technique based on the small-gain theorem.

[1] P. Kergus, C. Poussot-Vassal, F. Demourant, S. Formentin, Frequency-domain data-driven control design in the Loewner framework, 20th IFAC World Congress.
[2] P. Kergus, S. Formentin, C. Poussot-Vassal, F. Demourant, Data-driven control design in the Loewner framework: Dealing with stability and noise, European Control Conference.
[3] P. Kergus, M. Olivi, C. Poussot-Vassal, F. Demourant, From reference model selection to controller validation: Application to Loewner Data-Driven Control, IEEE Control Systems Letters and to be presented at the 58th Conference on Decision and Control.
[4] A. Bazanella, L. Campestrini, D. Eckhard, Data-driven controller design: the H2 approach, Springer Science & Business Media, 2011.
[5] D. Piga, S. Formentin, A. Bemporad, Direct data-driven control of constrained systems, IEEE Transactions on Control Systems Technology.
[6] D. Selvi, D. Piga, A. Bemporad, Towards direct data-driven model-free design of optimal controllers, in: European Control Conference, IEEE, 2018.

9 Mirko Mazzoleni, Matteo Scandella, Simone Formentin and Fabio Previdi (IT)

Affiliation: University of Bergamo

Title: A note on the numerical solutions of kernel-based learning problems

Abstract: In the last decade, kernel-based learning approaches typically employed for classification and regression have shown outstanding performance also in dynamic system identification. For this reason, they are now widely recognized as convenient tools to solve complex model-based control design problems. A key assumption in such learning techniques is that the kernel matrix is non-singular. However, due to limited machine precision, this might not be the case in many practical applications. In this work, we analyze the above problem and

show that such an apparent disadvantage actually introduces additional freedom, e.g., to enforce sparsity or to accurately solve ill-conditioned problems such as semi-supervised regression.

10 Atte Aalto and Jorge Goncalves (LU)

Affiliation: Luxembourg Centre for Systems Biomedicine (LCSB), University of Luxembourg

Title: Linear system identification from ensemble snapshot observations

Abstract: Modeling gene expression is an important problem in systems biology. Accurate models enable prediction of the effects of perturbations on the system, finding sources of diseases, targets for drugs, and so on. State-of-the-art modeling is based on time series data of gene expression, but due to high cost of experiments, the sampling frequency is typically low, and the overall amount of data is small, opposed to high system dimension. New experimental techniques have recently been adopted that enable gene expression measurements on single cell resolution for thousands of cells at a time. Unfortunately, the cells are destroyed in the measurement process, and so the data consist of snapshots of representative sub-populations, measured at different times. The sheer amount of data produced by these new single-cell techniques far exceeds what is obtained with older batch techniques, but it is not clear how such data should be used in modeling. This is the problem studied in this work. In particular, we study linear system identification from single-cell data. We introduce a method based on tracking the evolution of the distribution of cells over time. The idea is to look at two consequtive snapshot observations, propagate the earlier observations through the candidate model, and compare the propagated observation distribution to the later observation distribution using the discretized Jensen-Shannon divergence.

11 Marino Gavidia (LU)

Affiliation: University of Luxembourg

Title: Early detection of heart attacks and atrial fibrillations

Abstract: Atrial fibrillation (AF) affects about 2% to 3% of the population, and this percentage increases with age. The critical transition from Healthy rhythm to AF typically happens without warning. In some cases, it may switch back to normal rhythm on its own, or it may require treatment by drugs or by electrical shocks, also known as cardioversion. Generally, there are two forms of CTs at different time scales: 1) slow time-varying evolution of the disease, which can take years (development of an arrhythmic remodeling) and 2) a relatively fast time-scale where hearts transition between normal rhythm and AF. AF affects mostly older populations and tends to degrade with age. In this case, healthy patients can start developing the disease by changes in the electric activity and structure in the heart years before seeing any symptoms. Detecting the disease early could provide a chance for patients to change their lifestyle and habits. Healthy patients are unlikely to get AF. Hence, the system can be seen with a single (normal) rhythm. With age, AF can appear from changes in the system dynamics, which eventually will lead to the establishment of two possible trajectories (healthy and AF). The CT here is the change in dynamical parameters that will lead to the establishment of the disease. Eventually, the disease progresses to persistent AF. A totally different type of CT occurs when the disease is already established and the heart can switch between two stable trajectories: normal rhythm and AF. This occurs in a much faster time-scale and the CT. By predicting the switch between normal rhythm and AF allows patients to take drugs that can prevent the switch to AF.

12 Clarisse Bosman Barros, Roland Tóth and Hans Butler (NL)

Affiliation: Eindhoven University of Technology, Control Systems group

Title: Modeling and Identification of Piezoelectric Actuators: Vibration, Creep and Hysteresis

Abstract: Piezoelectric actuators are used in nanopositioning stages due to their large force generation, fast response, low power consumption and high control precision. The predominant behavior of these actuators can be captured in terms of vibration, creep and hysteresis effects, resulting from the properties of internal material dynamics, especially in terms of the alignment process of the crystalline domains. Depending on the amplitude and frequency range of operation, one of these behaviors is predominant and a simplified model can be sufficient to characterize the resulting dynamics of the actuator. However, for more complex operations, Hammerstein models with static or dynamic nonlinearities can be efficiently used to capture the cited behaviors.
In literature, vibration is characterized as a linear dynamic model. For identification, usually a frequency response is measured and a transfer function is fitted to the measured response. The creep effect can be characterized and identified the same way, although non-linear logarithmic models are also available and identified through curve-fitting. There are dozens of non-linear model types for the hysteresis behavior, e.g. Preisach model, each associated with specific identification techniques.
In our work, we provide a through overview of the modelling and identification methods for dynamical responses of piezoelectric actuators suitable for nanopositioning in wafer stages.

13 Enzo Evers, Bram de Jager, Tom Oomen (NL)

Affiliation: Eindhoven University of Technology, Control System Technology group

Title: Local Rational Approximation with Prescribed Poles for Improved Frequency Response Function Identification

Abstract: A key step in experimental modeling of mechatronic systems is Frequency Response Function (FRF) identification. Applying these techniques to systems where measurement time is limited leads to a situation where the accuracy of the identified model is deteriorated by transient dynamics. In this poster an identification procedure is presented that mitigates these transient dynamics by employing local parametric modeling techniques. To improve the modeling accuracy, prior knowledge from different domains and applications can be straightforwardly included. This prior knowledge is transformed to the local domain using a Mobius transfor- mation. It is shown that the presented framework leads to accurate identification results.

14 Fahim Shakib, Sacha Pogromsky, Alexey Pavlov, Nathan van de Wouw (NL)

Title: Fast Identification of Continuous-Time Lur’e-type Systems with Stability Certification

Affiliation: Eindhoven University of Technology, Dynamics and Control group

Abstract: An approach for parametric system identification for the class of continuous-time Lur’e-type systems using only steady-state input and output data is proposed.
An output error criterion constrained to the set of convergent models is minimized, which enforces a stability certificate on the identified model. To compute the steady-state model response efficiently, we adopt the Mixed-Time-Frequency (MTF) algorithm. Using the MTF

algorithm, we present a method to efficiently and exactly compute the gradient of the cost function. Starting with an initial convergent model estimate, the developed identification algorithm optimizes parameter estimates. The proposed approach is successfully applied in an experimental case study in mechanical ventilation, where parameters of a first-principles model are identified.

15 Jan Decuyper, J. Schoukens and K. Tiels (NL)

Affiliation: Vrije Universiteit Brussel

Title: Decoupling multivariate polynomials of sensitive nonlinear state-space models using multiple shooting

Abstract: Nonlinear state-space models have proven to be successful in a wide variety of applications. However powerful, the resulting models tend to be complex models, described by a large number of parameters. In many cases interpretability is preferred over complexity. Recent work has focused on reducing the complexity of such models by translating the multivariate polynomial parts into sets of univariate polynomials. This decoupling typically involves an approximation, resulting in slightly modified nonlinear state-space models. Some models may be sensitive to this modification, rendering them unstable. The resulting unbounded simulation output leads to an unbounded cost, which hinders further optimisation of the model. In this work such stability issues are mitigated by further tuning of the model on subrecords of the data. The latter is known as multiple shooting.

16 Karthik Ramaswamy, Paul M.J. Van den Hof, Arne G. Dankers (NL)

Affiliation: Eindhoven University of Technology, Control Systems group

Title: Generalized sensing and actuation schemes for local module identification in dynamic networks

Abstract: For the problem of identifying a target module that is embedded in a dynamic network with known interconnection structure, different sets of conditions are available for the set of node signals to be measured and the set of excitation signals to be applied at particular node locations. In previous work these conditions have typically been derived from either an indirect identification approach, considering external excitation signals as inputs, or from a direct identification approach, considering measured node signals as inputs. While both approaches lead to different sets of (sufficient) conditions, in this paper we extend the flexibility in the sufficient conditions for selection of excitation and measured node signals, by combining both direct and indirect approaches. As a result we will show the benefits of using both external excitation signals and node signals as predictor inputs. The provided conditions allow us to design sensor selection and actuation schemes with considerable freedom in order to consistently identify a target module.

17 Koen Tiels, Antonio H. Ribeiro, Jack Umenberger, Thomas B. Schön, Luis A. Aguirre (SW)

Affiliation: UFMG, Uppsala University

Title: On the Smoothness of Nonlinear System Identification

Abstract: In this work, new light is shed onto optimization problems resulting from prediction error parameter estimation of linear and nonlinear systems. It is shown that the ``smoothness" of the objective function depends both on the simulation length and on the decay rate of the prediction model. More precisely, for regions of the parameter space where the model is not contractive, the Lipschitz constant and β-smoothness of the objective function might blow up exponentially with the simulation length, making it hard to numerically find minima within those regions or, even, to escape from them. In addition to providing theoretical understanding of this problem, this work also proposes the use of multiple shooting as a viable solution. The proposed method minimizes the error between a prediction model and observed values. Rather than running the prediction model over the entire dataset, as in the original prediction error formulation, multiple shooting splits the data into smaller subsets and runs the prediction model over each subdivision, making the simulation length a design parameter and making it possible to solve problems that would be infeasible using a standard approach. The equivalence with the original problem is obtained by including constraints in the optimization. The method is illustrated for the parameter estimation of nonlinear systems with chaotic or unstable behavior, as well as on neural network parameter estimation.

18 Fredrik Ljungberg, Martin Enqvist (SW)

Affiliation: Electrical Engineering, Linköping University

Title: Obtaining Consistent Parameter Estimators for Second-order Modulus Models

Abstract: This work deals with the issue of obtaining consistent parameter estimators in nonlinear regression models where the regressors are second-order modulus functions, which is a structure that is often used in models of marine vessels. It is shown that the accuracy of an instrumental variable estimator can be improved by conducting experiments where the input signal has a static offset of sufficient amplitude and the instruments are forced to have zero mean. The proposed method is then evaluated in a simulation example.

19 Isabel Haasler, Axel Ringh, Yongxin Chen, Johan Karlsson (SW)

Affiliation: KTH Royal Institute of Technology

Title: Estimating ensemble flows on a hidden Markov chain

Abstract: We propose a new framework to estimate the evolution of an ensemble of indistinguishable agents on a hidden Markov chain using only aggregate output data. This work can be viewed as an extension of the recent developments in optimal mass transport and Schrödinger bridges to the hidden Markov chain setting. The flow of the ensemble is estimated by solving a maximum likelihood problem, which has a nice convex approximation, and we develop a fast numerical algorithm for it. We illustrate in numerical examples how this framework can be used to track the flow of identical and indistinguishable dynamical systems.

20 Mina Ferizbegovic, Jack Umenberger, Håkan Hjalmarsson and Thomas B. Schön (SW)

Affiliation: KTH Royal Institute of Technology, Uppsala University

Title: Learning robust LQ-controllers using application oriented exploration

Abstract: This poster concerns the problem of learning robust LQ-controllers, when the dynamics of the linear system are unknown. First, we propose a robust control synthesis method to minimize the worst-case LQ cost, with probability 1 − \delta, given empirical observations of the system. Next, we propose an approximate dual controller that simultaneously regulates the system and reduces model uncertainty. The objective of the dual controller is to minimize the worst-case cost attained by a new robust controller, synthesized with the reduced model uncertainty. The dual controller is subject to an exploration budget in the sense that it has constraints on its worst-case cost with respect to the current model uncertainty. In our numerical experiments, we observe better performance of the proposed robust LQ regulator over the existing methods. Moreover, the dual control strategy gives promising results in comparison with the common greedy random exploration strategies.

POSTER SESSION II

TUESDAY SEPTEMBER 24, 2019

1 Jeremy Coulson (BE)

Affiliation: ETH Zurich, Automatic Control Laboratory

Title: Model-based vs Data-driven Linear Quadratic Tracking Control

Abstract: Data-driven control is an alternative to the classical model-based control paradigm that does not identify a parametric model of the plant. In this poster, we present subspace-type data-driven linear quadratic tracking control methods. The basic method is the one from "Data-driven
simulation and control", International Journal of Control, 81(12):1946--1959, 2008. This method is developed under the assumption that the data is exact. The main question that we study is how to modify the method so that it performs well with noisy data. The following modifications of the basic method are proposed and compared empirically:

1. pseudo-inverse,
2. ℓ_1 - norm regularization,
3. unstructured low-rank approximation,
4. structured low-rank approximation, and
5. nuclear norm regularization.

2 Noël Hallemans, Rik Pintelon, John Lataire (BE)

Affiliation: Vrije Universiteit Brussel, departement ELEC

Title: Nonparametric Identification of Linear Time-Varying Systems using Gaussian Processes

Abstract: Linear time-varying systems are a class of systems with dynamics evolving in time. For these systems we can define a time-varying transfer function. Accordingly, for each frequency a time-varying gain can be attributed to the system as opposed to a fixed gain in the case of time-invariant systems. The goal of this study is to estimate this time-varying transfer function based on observed data.
There already exist methods to identify linear time-varying systems nonparametrically. The problem boils down to capturing the time-varying gains, which is solved in the literature by imposing basis functions and projecting the time-varying gains on the space spanned by these basis functions. In this research, however, we don't use basis functions but rather Gaussian processes to capture the time-variation. Models based on Gaussian processes are very flexible and have the particular property that their model structure is continuously tunable. Furthermore, the model structure can be estimated during the identification process and not afterwards as opposed to classical basis function approaches. Hence, the use of Gaussian processes is of great advantage when modelling linear time-varying systems.
The main advantage of this new identification method using Gaussian processes is the fact that the user should not choose a predefined model structure. Hence, it contributes to the use of system identification by non-experts.

3 Oliver Lauwers (BE)

Affiliation: KU Leuven

Title: Centroids of weighted cepstral clusters as estimators of average dynamics

Abstract: The weighted cepstral distance for time series serves as an interpretable similarity measure, closely linked to notions stemming from systems theory, statistics and information theory. It mimicks a model norm on the underlying dynamics of signals, without the need to actually identify these models. It therefore is an excellent similarity measure for clustering purposes in application fields that traditionally rely on system identification.
In this poster, we interpret the results of clustering based on the weighted cepstral distance. The center of such a cluster can be interpreted as the geometric mean of the transfer functions of the generative dynamics of all signals present in the cluster. This is a less biased estimator of the average dynamics than the euclidean average.
Combining these results with cepstral system identification, allows to identify a minimally biased transfer function from several realizations of the output of the dynamics, which may differ through noise and errors.

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4 Pawel Wachel (BE)

Affiliation: Wroclaw University of Science and Technology

Title: Exponentially weighted aggregation for noise cancellation in switching-mode nonlinear systems

Abstract: We focus on the noise cancellation problem for the class of non-linear dynamic systems with nonlinear characteristics that reveal time-varying behavior. It is assumed that the considered systems can change their mode in a priori known range of modes but the switching moments are unknown (and cannot be directly detected).
In the considered approach, based on the noisy measurements of the system output, exponentially weighted aggregation is used to estimate noise-free counterparts of the possessed output observations.

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5 Péter Zoltán Csurcsia, Bart Peeters, Johan Schoukens (BE)

Affiliation: Vrije Universiteit Brussel and Siemens Industry Software

Title: User-friendly Nonlinear Framework for Industrial Measurements with Multiple Input

This work introduces a user-friendly estimation framework for industrial measurements of vibro-acoustic systems with multiple input. Many mechanical structures are nonlinear and there is no unique solution for modeling nonlinear systems. This is especially true when multiple-input, multiple-output systems are observed. This paper addresses the questions related to the user-friendly processing of MIMO measurements with respect to the design of experiment and the analysis of the measured data. When the proposed framework is used, it is easily possible a) to decide, if the underlying system is linear or not, b) to decide if the linear framework is still accurate (safe) enough to be used, and c) to tell the unexperienced user how much it can be gained using an advanced nonlinear framework. The proposed nonparametric industrial framework is illustrated on a on the ground vibration testing of an electrical airplane.

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6 Philippe Dreesen, I. Markovsky, K. Usevich (BE)

Affiliation: Vrije Universiteit Brussel

Title: Data-driven simulation using nuclear norm matrix completion

Abstract: In the data-driven simulation problem, the output of a linear dynamic system is simulated for a given input, without explicitly building a model of the system. Instead, a partially known mosaic block-Hankel matrix is built from the input-output data, which is to be completed for the unknown values of the simulated output sequence. Therefore, we consider two data sets, namely a given trajectory of the system and a given input trajectory without the output. The input-output trajectory of the system defines the left-most part of the block-Hankel matrix, which is completely known. The second part of the data, which contains the inputs and the to-be-simulated outputs, defines the right-most part of the block-Hankel matrix, and hence has missing elements for the simulation outputs. The data-driven simulation problem can then be solved by completing the unknown part of the block-Hankel matrix such that the matrix has minimal rank. The rank minimization hereby imposes that both trajectories are of the same underlying system. Instead of solving the rank minimization problem, which is NP hard, we consider the nuclear norm heuristic as a convex relaxation. In previous work, we illustrated that the nuclear norm heuristic is successful in computing the simulated output, provided that a suitable scaling factor of the given data set is applied. Here, we study this effect, employing the tools of Gillard and Usevich (Int J Forecast 34, 582-597, 2018) to derive a bound on the required scaling factor.

7 Régis Ouvrard, Guillaume Mercère, Thierry Poinot, Frédéric Jiguet, Lauriane Mouysset (FR)

Affiliation: Université de Poitiers

Title: Dynamic models for bird population—A parameter-varying partial differential equation identification approach

Abstract: In order to study the global decline of biodiversity, accurate models of animal population dynamics are required. In our study, this challenging problem of biodiversity decline analysis is tackled by modelling the dynamics of bird populations. More specifically, a new data-driven modelling of bird population dynamics is suggested which resorts to a parameter-varying partial differential equation model, the Galerkin method and the proper orthogonal decomposition. The parameter-varying formulation allows us to introduce in models prior information such as temperatures or landscape patterns. Hence, such models can be used to study the impact on biodiversity of the global warming or the agricultural intensification, for instance. In order to deal with the specific conditions of ecological applications, a specific attention is paid to the initialization as well as the implementation of an iterative identification procedure based on 3D partial moments and a Levenberg–Marquardt algorithm. These tools are tested on the data-driven modelling of the population of European Stonechat (Saxicola torquatus), a European common bird species, by using data from the national French Breeding Bird Survey and the CORINE Land Cover. The perspectives are to model specific community of birds in order to evaluate the effect of global changes in population trends and to develop tools to help decision makers take into account biodiversity goals into public policies.

8 Szymon Gres, Michael Döhler, Palle Andersen, Laurent Mevel (FR)

Affiliation: Aalborg University, Structural Vibration Solutions

Title: Kalman filter-based stochastic subspace identification under mixed stochastic and periodic excitation

Abstract: System identification methods are applied to estimate the eigenstructure of linear time invariant mechanical systems from output-only measurements under ambient excitation conditions. Often, the excitation is assumed to be white and stationary, which is frequently violated, e.g. in the presence of periodic excitation originating from rotating components of the structure during its operation. The periodic excitation may render the estimation difficult, and periodic modes often disturb the estimation of close structural modes. The aim of this work is to develop a subspace identification method for the estimation of the structural parameters while rejecting the influence of the periodic subsignal. In the proposed approach the periodic subsignal is predicted from the outputs with a non-steady state Kalman filter, and then removed from the original output signal by an orthogonal projection. Consequently, the parameters of the periodic subsystem are rejected from the common observability matrix, and the eigenstructure of the underlying mechanical system is identified. The proposed method is validated on numerical Mote Carlo simulations and applied to both a laboratory example and a full scale structure in operation.

9 Stefano Magni, Alexander Skupin, Jorge Goncalves (LU)

Affiliation: University of Luxembourg, Luxembourg Centre for Systems Biomedicine

Title: Modeling of Single-Cell RNA-Seq Data by Chemical Master Equation and Fokker-Plank Equation

Abstract: Single-cell RNA-Sequencing (sc RNA-Seq) is an experimental technique which is revolutionizing the way biologists can study cells at the level of gene expression. Sc RNA-Seq techniques allow nowadays to measure gene expression of almost each gene in the genome, for thousands of individual cells simultaneously. The output of such measurements are so called digital gene expression matrices, high-dimensional data which contain a great amount of information. Since these experimental techniques have developed only recently, the data analysis and modeling approaches to process them, which play a crucial role in extracting this information, are only now beginning to be widely developed. Here we consider to model gene-expression dynamics from sc RNA-Seq data by means of the chemical master equation, and by means of the chemical Fokker-Planck equation. These approaches are particularly suitable here since gene expression is an intrinsically stochastic phenomenon, for which a deterministic description might not always be a valid approximation. Despite their high dimensionality, usually it is possible to generate sc RNA-Seq data for only a very limited number of time-points. Nevertheless, at every time-point a subset of the whole population of individual cells is measured. Thus, we aim at using these data to reconstruct the probability distributions of gene expressions, in order to implement the above mentioned modeling strategies. Sc RNA-Seq data are particularly interesting in the light of investigating developmental aspects of cells, i.e. how a population of cells evolve in time from one cell type, to one or more other cell-types, a phenomenon referred to as cell-fate determination. Models of this kind inferred from sc RNA-Seq data would be particularly useful in shading light over the biological process of cell-fate determination, especially when cells from two conditions (e.g. healthy/disease) are compared, in which case two models can be inferred, and the comparison among the two be used to enlighten the differences among the two conditions.

10 Vladimir Levin (LU)

Affiliation: University of Luxembourg

Title: Do “Speed Bumps” Prevent Accidents in Financial Markets?

Abstract: Is it true that speed bumps level the playing field, make financial markets more stable and reduce negative externalities of high-frequency trading (HFT) firms? We examine how the implementation of a particular speed bump – Midpoint Extended Life order (M-ELO) on Nasdaq impacted financial markets stability in terms of occurrences of mini-flash crashes in individual securities. We use high-frequency order book message data around the implementation date and apply difference-in-differences analysis to estimate the average treatment effect of the speed bump on market stability and liquidity provision. The results suggest that the introduction of the M-ELO decreases the average number of crashes on Nasdaq compared to other exchanges by 4.7%. Liquidity provision by HFT firms also improves. These findings imply that technology-based solutions by exchanges are feasible alternatives to regulatory intervention towards safer markets.

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11 Kim Batselier (NL)

Affiliation: Delft University of Technology

Title: Tensor Networks for Nonlinear System Identification

Abstract: Polynomial nonlinear models suffer from the curse of dimensionality. That is, the number of model parameters grows exponentially with both the degree of the polynomial as the number of variables. Tensor networks will be shown in this poster to be an efficient way to lift this curse of dimensionality, enabling for the first time the identification of highly nonlinear polynomial models. The goal of this poster is to explain what tensor networks are and how they can be used specifically for nonlinear system identification.

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12 Lizan Kivits, P.M.J. Van den Hof (NL)

Affiliation: Eindhoven University of Technology, Control Systems group

Title: Identification of physical systems, a dynamic network approach

Abstract: System identification problems utilizing a prediction error approach are typically considered in an input/output setting, where a directional cause-effect relationship is presumed and transfer functions are used to estimate the causal relationships. In more complex interconnection structures, as e.g. appearing in dynamic networks, the cause-effect relationships can be encoded by a directed graph. Physical dynamic networks are most commonly described by diffusive couplings between node signals, implying that cause-effect relationships between node signals are symmetric and therefore can be represented by an undirected graph. This contribution shows how (prediction error) identification methods developed for linear dynamic networks can be configured to identify components in (undirected) physical networks with known topology.

13 Mannes Dreef (NL)

Affiliation: Eindhoven University of Technology, Control Systems group

Title: Asymptotic Variance Expression for Identification with Switched Controllers

Abstract: The direct method for closed-loop identification generally requires presence of an external reference signal to ensure informativity. Another possibility to achieve this is by switching between multiple controllers, for which an external excitation is not required. In this work, the effect of the particular choice of the switching controllers is investigated by analysing the variance of estimated transfer functions using an 'asymptotic in model order and data'-approach. The analysis provides information on the distance measure between these controllers. This measure and the double-Youla parametrization forms a basis for a synthesis approach that aims at minimizing the variance on the transfer function, while still achieving a certain control performance of the closed-loop system.

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14 Manon Kok, Ive Weygers, Karsten Eckhoff, Thomas Seel, Henri De Vroey, Hans Hallez, Mark Versteyhe, Kurt Claeys (NL)

Affiliation: Delft University of Technology

Title: Estimating relative orientation of connected segments using inertial sensors

Abstract: In this work, we present a novel method to estimate the relative orientation of connected segments, e.g. human body segments, using inertial sensors [1, 2]. Even though we do not include any magnetometer measurements, we show that the estimate of the relative heading does not drift over time because of the inclusion of a biomechanical constraint. Previous work claims that incorporating biomechanical constraints, the sensors' relative orientation becomes observable as long as the subject is not standing completely still [3]. Based on ongoing work, we discuss a method to assess under which conditions the relative orientation is indeed observable.

[1] Ive Weygers, Manon Kok, Henri De Vroey, Hans Hallez, Tommy Verbeerst, Mark Versteyhe, and Kurt Claeys. IMU-based joint kinematics for connected segments. In Proceedings of the 41st Engineering in Medicine and Biology Conference (EMBC), Berlin, Germany, July 2019.
[2] Ive Weygers, Manon Kok, Hans Hallez, Henri De Vroey, Tommy Verbeerst, Mark Versteyhe, and Kurt Claeys. Drift-free inertial sensor-based joint kinematics for long-term arbitrary movements. Submitted, 2019.
[3] M. Kok, J. D. Hol, and T. B. Sch¨on. An optimization-based approach to human body motion capture using inertial sensors. In Proceedings of the 19th World Congress of the International Federation of Automatic Control, pages 79–85, Cape Town, South Africa, August 2014.

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15 Shengling Shi, Xiaodong Cheng, Paul Van den Hof (NL)

Affiliation: Eindhoven University of Technology, Control Systems group

Title: Signal allocation for generic identifiability of dynamic subnetworks

Abstract: This work considers the setting of linear dynamic networks, where vertices represent measured signals and directed edges among vertices denote transfer functions. Particularly, a synthesis problem for generic identifiability of subnetworks is addressed: given a dynamic network, where excitation signals can be allocated such that a subpart of the network can be uniquely identified from data. A local synthesis procedure is first introduced to allocate signals such that one transfer function of interest becomes generically identifiable. Then to achieve generic identifiability for multiple transfer functions of interest and thus for general subnetworks, a graph structure called directed rooted graph is introduced to cover the subnetwork of interest, such that assigning signals to the roots of rooted graphs guarantees its generic identifiability. An algorithm is also developed such that the synthesis procedure can be conducted automatically.

16 Tom Bloemers, Roland Tóth, Tom Oomen (NL)

Affiliation: Eindhoven University of Technology, Control Systems group

Title: Data-driven LPV controller synthesis in the frequency-domain

Abstract: Synthesis of linear time-invariant (LTI) controllers directly from frequency response function (FRF) measurements of the plant has proven itself as a powerful approach in many industrial applications. Many systems encountered in practice exhibit nonlinear behavior, well-described by parameters that vary over time, often manifesting in terms of position or operating condition dependent dynamics. Controlling these types of systems through tools stemming from the LTI framework typically poses strong limitations on the achievable performance. In light of increasing performance expectations, the explicit incorporation of parameter-dependent dynamics becomes a necessity. However, this requires an extension of the industrial tools currently used for FRF based control synthesis. The framework of linear parameter-varying (LPV) systems has proven to be an effective tool to design controllers for nonlinear systems, supported by a well-developed time-domain control and identification theory, with many successful applications. However, there is a lack of frequency-domain LPV control design methods based on FRF measurements. With this poster, first steps towards the extension of data-driven LTI control approaches to the LPV framework are presented in the frequency-domain. The proposed approach leverages a global LPV controller parametrization for which local stability and performance guarantees are obtained.

17 Mohamed Rasheed-Hilmy Abdalmoaty, Håkan Hjalmarsson (SW)

Affiliation: KTH Royal Institute of Technology

Title: Identification Using Optimal Estimating Functions

Abstract: The poster concerns the problem of parameter estimation in fairly general stochastic nonlinear models. We present an approach that may be used to systematically construct optimal estimators, within a predefined class, using only a partial specification of the probabilistic model. Unless the model is Gaussian, this leads to estimators that are asymptotically uniformly more accurate than linear prediction error methods when quadratic criteria are used.

18 Othmane Mazhar (SW)

Affiliation: KTH Royal Institute of Technology

Title: Finite impulse response models in low and high dimension: A non-asymptotic analysis of the least squares estimators

Abstract: We consider a finite impulse response system with centered independent sub-Gaussian design covariates, and noise components not necessarily identically distributed. We derive non-asymptotic near optimal estimation and prediction bounds of its parameters for the least squares estimate in the low dimension case and the panalized least squares by the nuclear norm of the Hankel operator in the high dimension case. Our results are based on concentration inequalities on the norm of sums of dependent covariate vectors and on the singular values of

their covariance operator, where the dependence arises from the time shift structure of the time series. These results generalize the known bounds for the independent case.

19 Robert Mattila, Inês Lourenço, Cristian R. Rojas , Vikram Krishnamurthy and Bo Wahlberg (SW)

Affiliation: KTH Royal Institute of Technology, Division of Decision and Control Systems,

Title: Estimating Private Beliefs Based on Observed Decisions

Abstract: We consider sequential stochastic decision problems in which an agent optimizes its local utility by solving a stochastic program and, subsequently, announces its decision to the world. Given this action, we study the problem of estimating the agent's private belief -- that is, its posterior distribution over the set of states of nature based on its private observations. We determine the set of private beliefs that are consistent with public data by leveraging techniques from inverse optimization. As illustrative examples, we consider estimating the private belief of an investor in regime-switching portfolio allocation, and discuss how the studied problem connects to inverse filtering problems.

20 Rodrigo Gonzalez, Siqi Pan, Cristian R. Rojas, James S. Welsh (SW)

Affiliation: KTH Royal Institute of Technology, Division of Decision and Control Systems

Title: Consistency of the Simplified Refined Instrumental Variable Method for Continuous-time Systems: Analysis and Design

Abstract: For many years, the Simplified Refined Instrumental Variable Method for Continuous-time Systems (SRIVC) has been widely used for identification. It is well known that the intersample behavior of the input signal influences the quality and accuracy of this method when estimating and simulating continuous-time models. This important fact, however, has been somewhat overlooked in the existing literature. The purpose of this work is two-fold: we first present a comprehensive analysis of the consistency of the SRIVC estimator that takes into consideration the intersample behavior of the signals of interest, and then propose a SRIVC-based estimator that is empirically shown to be consistent for arbitrary input signals, which cannot necessarily be interpolated through hold reconstructions. The results are supported by simulation examples.

21 Koen Tiels, Antonio H. Ribeiro, Carl Andersson, Niklas Wahlström, Thomas B. Schön (SW)

Affiliation: UFMG, Uppsala University

Title: Deep Convolutional Networks in System Identification

Abstract: Recent developments within deep learning are relevant for nonlinear system identification problems. In this paper, we establish connections between the deep learning and the system identification communities. It has recently been shown that convolutional architectures are at least as capable as recurrent architectures when it comes to sequence modeling tasks. Inspired by these results we explore the explicit relationships between the recently proposed temporal convolutional network (TCN) and classic system identification model structures. We end the paper with an experimental study where we provide results on two real-world problems, the well-known Silverbox dataset and a newer dataset originating from ground vibration experiments on an F-16 fighter aircraft.

22 Adrià Garriga-Alonso, Carl Edward Rasmussen (UK)

Affiliation: University of Cambridge

Title: Amortised Inference in Gaussian Processes with Input Noise

Authors: Adrià Garriga-Alonso and Abstract: Nonlinear regression algorithms often assume that the inputs are observed exactly and the outputs are corrupted by noise. In autoregressive time series forecasting or system identification, this assumption is violated: both inputs and outputs are measured, and thus corrupted, in the same way. We develop a Bayesian prior and corresponding approximate inference algorithm that take this into account. Naively, the cost of storing the approximate posterior scales unfavourably with the number of data points. We mitigate this by representing it using a neural network function approximator and fewer parameters. Experimentally, we compare this approach in efficiency and accuracy to other approximate and exact inference methods.