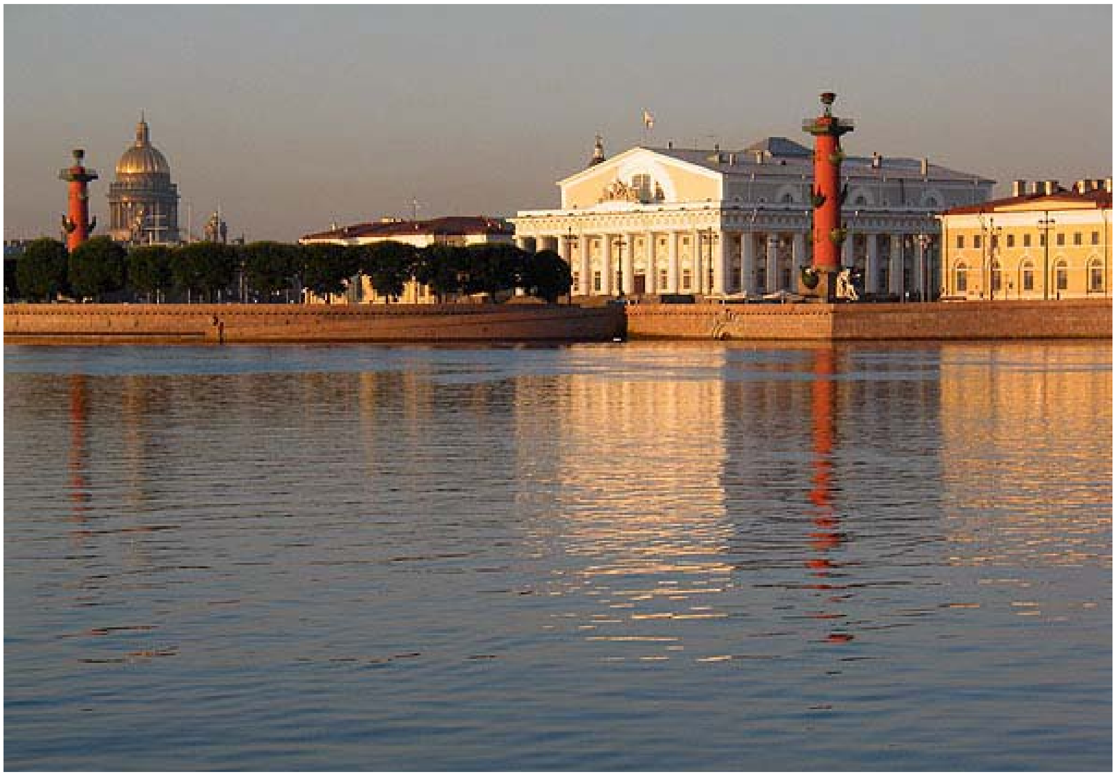

6TH SWEDISH-RUSSIAN CONTROL CONFERENCE

SWERUCON'11

SweRuCon
2011

SAINT PETERSBURG

SEPTEMBER 19-20, 2011

Conference Organizers:
National Research University of Information Technologies, Mechanics and Optics
Institute of Problems in Mechanical Engineering of Russian Academy of Sciences

Conference Co-Chairs:
Lennart Ljung,
Anders Rantzer,
Alexander Fradkov (fradkov@mail.ru)

Conference Vice-Chair:
Alexey Bobtsov (bobtsov@mail.ru)

Conference Secretary:
Natalia Dudarenko (dudarenko@yandex.ru)

SweRuCon 2011 CONFERENCE PROGRAM

Monday September 19, 2011

09:00-09:20	Registration
09:20-09:30	Opening Ceremony.
Keynote Session, 09:30-10:30	
09:30-10:00	**Anders Rantzer.** Distributed Control of Positive Systems
10:00-10:30	**Alexander Kurzhanski.** The mathematics of multiagent control
Coffee Break, 10:30-10:50	
Regular Session I, 10:50-12:10	
10:50-11:10	**Rolf Johansson.** Observer-based Strictly Positive Real (SPR). Switching Output Feedback Control
11:10-11:30	**Boris Polyak, Pavel Scherbakov, Michael Khlebnikov.** Reducing the number of control states or outputs in linear systems
11:30-11:50	**Cristian Rojas.** Sparse Estimation based on a Validation Criterion
11:50-12:10	**Vladimir Kharitonov.** Lyapunov functionals and matrices
Lunch, 12:30-14:00	
Regular Session II, 14:00-15:20	
14:00-14:20	**Wolfgang Birk.** Reconfiguration of Multivariable Decentralized Controllers Based on Closed-Loop Sensitivity Factorization
14:20-14:40	**Gennady Leonov, Nikolay Kuznetsov.** Absolute stability of control system: hidden oscillations in Aizerman and Kalman problems
14:40-15:00	**Thomas Schon.** System Identification of Nonlinear State-Space Models
15:00-15:20	**Sergey Gusev.** From Kalman-Yakubovich-Popov Lemma To Hilbert's 17-th Problem and Back Again
Walking City Tour or Hermitage Tour (depending on the weather), 15:30-18:30	
Welcome reception, 19:00-21:00	

Tuesday September 20, 2011

Regular Session III, 09:30-10:50	
09:30-09:50	**Michael Khlebnikov, Boris Polyak.** Design of linear dynamical output feedback controller for rejection of persistent disturbances
09:50-10:10	**Martin Enqvist.** Invertible time series and closed-loop identification of nonlinear systems
10:10-10:30	**Andrey Polyakov.** Nonlinear Feedback Design for Fixed-Time Stabilization of Linear Plants
10:30-10:50	**Egi Hidayat.** Laguerre domain identification of continuous linear time delay systems from impulse response data
Coffee Break, 10:50-11:10	
Regular Session IV, 11:10-12:30	
11:10-11:30	**Bengt Lennartson and Oskar Wigström (Sweden), Alberto Vergnano (Italy).** High level scheduling of energy optimal trajectories applied to robot coordination
11:30-11:50	**Alexey Bobtsov, Anton Pyrkin**. Simple Adaptive Output Control for Nonlinear Systems with Time-Delay
11:50-12:10	**Andrey Barabanov.** Fast identification of the voiced speech signal
12:10-12:30	**Anders Robertsson.** On Optimal Paths, Tracking and Constraint-based control for Robotic applications
Lunch, 12:30-14:00	
Regular Session V, 14:00-15:20	
14:00-14:20	**Leonid Freidovich, Anton Shiriaev.** On global robust stabilization of the 3-state Moore-Greitzer model
14:20-14:40	**Anton Proskurnikov.** Absolute stability methods for consensus in nonlinear networks
14:40-15:00	**Alexander Medvedev.** Dynamical systems approach to endocrine regulation
15:00-15:20	**Anton Selivanov.** Adaptive synchronization of networks with delayed couplings
Coffee Break, 15:20-15:40	
Regular Session VI, 15:40-17:00	

15:40-16:00	**Margarida Martins da Silva.** Prediction error identification algorithms for anesthesia-related Wiener models
16:00-16:20	**Pavel Tochilin.** Output feedback control of the oscillating system under set-membership uncertainties
16:20-16:40	**Giacomo Como.** Stability analysis of transportation networks with multiscale driver decisions
16:40-17:00	**Alexander Fradkov.** Static Output Feedback Synchronization of Dynamical Networks
Technical tour: Museum of Optics, 17.00-18.30	
Banquet, 19:00-22:00	

SweRuCon'11 CONFERENCE PROGRAM IN DETAIL

Monday September 19, 2011

09:00-09:20 Registration

09:20-09:30 Opening Ceremony

Keynote Session, 09:30-10:30

09:30-10:00 **Anders Rantzer.** Distributed Control of Positive Systems

Affiliation: Lund University

Abstract: State space descriptions with nonnegative coefficients define an important class of dynamical systems, so-called positive systems, with many applications in science and technology. In particular, they appear naturally in economic theory and in the study of electrical power systems.

Positive systems have properties that are particularly attractive for distributed control. For example, they allow stability to be verified in a distributed way without conservatism. Moreover, optimal controllers with constraints can be designed using Positive Quadratic Programming.

This is a generalization of standard quadratic programming, which exploits positivity of coefficients in objective function and constraints.

10:00-10:30 **Alexander Kurzhanski.** The mathematics of multiagent control

Affiliation: Lomonosov Moscow State University

Abstract: This presentation gives an overview of mathematical problems and solution techniques on feedback and feed-forward goal-oriented control under obstacle and collision avoidance, for a team of controlled motions. This includes related problems of feedback team control and motion planning, as well as of restructuring the motion on-line in order to avoid obstacles.

Animation examples are also to be presented.

Coffee Break, 10:30-10:50

Regular Session I, 10:50-12:10

10:50-11:10	**Rolf Johansson.** Observer-based Strictly Positive Real (SPR). Switching Output Feedback Control

Affiliation: Lund University

Abstract: This contribution considers switching output feedback control of linear systems and variable structure systems. Theory for stability analysis and design for a class of observer-based feedback control systems is presented. It is shown how a circle criterion approach can be used to design an observer-based state feedback control which yields a closed-loop system with specified robustness characteristics. The approach is relevant for variable structure system design with preservation of stability when switching feedback control or sliding mode control is introduced in the feedback loop. It is shown that there exists a Lyapunov function valid over the total operating range and this Lyapunov function has also interpretation as a storage function of passivity-based control and a value function of an optimal control problem. The Lyapunov function can be found by solving a Lyapunov equation. Important applications are to be found in hybrid systems with switching control and variable structure systems with high robustness requirements. The method is useful for switching output feedback control also of non-SPR loop transfer functions.

References

R. Johansson, A. Robertsson and A. Shiriaev, Observer-based Strict Positive Real (SPR) Switching Output Feedback Control, *Proc. 43rd IEEE Conference on Decision and Control,* Dec. 14-17, 2004, Atlantis, Bahamas, pp. 2811-2816, 2004.

11:10-11:30	**Boris Polyak, Pavel Scherbakov, Michael Khlebnikov.** Reducing the number of control states or outputs in linear systems

Affiliation: Institute of Control Sciences V.A. Trapeznikov Academy of Sciences

Abstract: We investigate the new problem for linear control systems: find a stabilizing state feedback controller which depends on a small number of states or a static output feedback which depends on a small number of outputs. Such problem formulations are motivated with various real-life applications. The tool for solution is L1 optimization technique combined with LMI approach. Simulation results are highly promising, they demonstrate that the number of states or outputs for use in control can be strongly reduced without serious losses in performance.

11:30-11:50 **Cristian Rojas.** Sparse Estimation based on a Validation Criterion

Affiliation: KTH Royal Institute of Technology

Abstract: One long standing problem in estimation is model selection. In linear regression this amounts to selecting appropriate regressors among a large set of candidate regressors. The brute force approach of comparing all possible subsets using some cross-validation method leads to large combinatorial complexity. In order to overcome this problem, many approaches have been suggested. The LASSO (least absolute shrinkage and selection operator) is one of the early contributions to this field, and has been of tremendous influence. This algorithm performs minimization under a constraint of the L_1-norm of the parameter vector $\theta \in \mathbb{R}^n$. More precisely the criterion is

$$\begin{aligned} &\min_{\theta} V_N(\theta) \\ &\text{s.t.} \|\theta\|_1 \leq c. \end{aligned} \tag{1}$$

Above $V_N(\theta)$ is the least-squares cost function based on *N* samples. For linear regression problems the above problem is convex.

Integral to the application of the LASSO is the use of cross-validation or some information criterion, e.g. AIC, BIC or GCV, to determine the constant *c* in (1). This means solving (1) and then evaluating the performance of the estimate using, e.g., GCV, for different values of c and then picking the best *c*. While different search strategies for the best c can be devised, a drawback is that it is necessary to solve (1) multiple times. For large problems this can be restrictive. In this talk we turn the problem “upside down” and then appeal to AIC to come up with a good way to choose *c*, and we provide an asymptotic analysis of the proposed estimator.

11:50-12:10 **Vladimir Kharitonov.** Lyapunov functionals and matrices

Affiliation: Saint-Petersburg State University

Abstract: In this contribution we give an account of the present state of art in the area of quadratic functionals with prescribed time derivatives. There are several issues that will be addressed in this talk, in particular we focus on the structure of the functionals, we are interested also in lower and upper bounds for them. The functionals are de…ned by

special matrix valued functions known as Lyapunov matrices. The matrices are as important for the functionals, as the classical Lyapunov matrices are for the quadratic Lyapunov functions in the case of delay free systems. This explains the reason why we dedicate so much attention to existence and computation of the matrices. By definition Lyapunov matrices are solutions of a matrix delay equation which satisfy two additional properties. The delay matrix equation along with the properties is a counterpart of the classical Lyapunov matrix equation. One of our specific goals is to demonstrate that the computed quadratic functionals can be effectively used in the stability, and robust stability analysis of time delay systems.

Lunch, 12:10-14:00

Regular Session II, 14:00-15:20

14:00-14:20 **Wolfgang Birk.** Reconfiguration of Multivariable Decentralized Controllers Based on Closed-Loop Sensitivity Factorization

Affiliation: Luleå University of Technology

Abstract: This talk deals with the optimization of control structures for multivariable systems. When a controller with sparse structure is used to control a process with a more dense structure, then the closed loop performance may deviate from the desired one. This deviation can be characterized by a factorization of the closed loop sensitivity transfer matrix, which has already been shown by Zhames in 1981. Clearly, for decentralized and block decentralized controllers the deviation depends on the neglected dynamics and is reflected in the factorization with maintained structure.

It is shown how the factorization can be used to determine the structural changes that can lead to an improvement of the closed loop performance. From this, an incremental algorithm can be formulated that step-wise increases the controller complexity. Moreover, the sensitivity to variable scaling is discussed and how it can be resolved.

The proposed method is applied to a quadruple tank processes and a real life case, namely the air control system of a bark boiler, which is a waste to energy plant in pulp and paper making industries. The analysis results will be compared with the outcome from conventional control structure selection methods. The proposed method is now implemented in a software tool for interactive modeling, visualization and analysis of complex interconnected processes, called ProMoVis.

14:20-14:40 **Gennady Leonov, Nikolay Kuznetsov.** Absolute stability of control system: hidden oscillations in Aizerman and Kalman problems

Affiliation: Saint-Petersburg State University

Abstract: The method of harmonic linearization, numerical methods, and the applied bifurcation theory together open new opportunities for analysis of hidden oscillations of control systems [1-6]. In the present survey an analytical-numerical algorithm for hidden oscillations localization is discussed. Counterexamples construction to Aizerman's conjecture and Kalman's conjecture on absolute stability of control systems are considered.

References

[1] G.A. Leonov, N.V. Kuznetsov, Algorithms for Searching Hidden Oscillations in the Aizerman and Kalman. Problems *Doklady Mathematics*. 2011, Vol. 84, No. 1 (doi:10.1134/S1064562411040120).

[2] G.A. Leonov, N.V. Kuznetsov, V.I. Vagaytsev, Localization of hidden Chuas attractors, *Physics Letters A*. 2011, 375(23), 22302233 (doi:10.1016/j.physleta.2011.04.037)

[3] V.O. Bragin, V.I. Vagaitsev, N.V. Kuznetsov, G.A. Leonov, Algorithms for Finding Hidden Oscillations in Nonlinear Systems. The Aizerman and Kalman Conjectures and Chua's Circuits, *Journal of Computer and Systems Sciences International*. 2011, Vol. 50, No. 4, pp. 511-543 (doi:10.1134/S106423071104006X).

[4] G.A. Leonov, V.I. Vagaitsev, N.V. Kuznetsov, Algorithm for localizing Chua attractors based on the harmonic linearization method, *Doklady Mathematics*. 2010, Vol. 82, No. 1, pp. 663-666 (doi:10.1134/S1064562410040411).

[5] G.A. Leonov, V.O. Bragin, N.V. Kuznetsov, Algorithm for Constructing Counterexamples to the Kalman Problem, *Doklady Mathematics*. 2010, Vol. 82, No. 1, pp. 540-542 (doi:10.1134/S1064562410040101).

[6] G.A. Leonov, Efficient methods in the search for periodic oscillations in dynamical systems, *Journal of Applied Mathematics and Mechanics*, 2010, 74, pp. 24–50.

14:40-15:00 **Thomas Schon.** System Identification of Nonlinear State-Space Models

Affiliation: Linkoping University

Abstract: We are in this talk concerned with the problem of parameter estimation of a general class of nonlinear dynamic systems in state-space form. More specifically, a Maximum Likelihood (ML) framework is employed and an Expectation Maximisation (EM)

algorithm is derived to compute these ML estimates. The Expectation (E) step involves solving a nonlinear state estimation problem, where the smoothed estimates of the states are required. This problem lends itself perfectly to the particle smoother, which provides arbitrarily good estimates. We will show how to identify a nontrivial Wiener model as an example of how the proposed algorithm can be used.

Personal home page for more information: www.control.isy.liu.se/~schon**/**

15:00-15:20 **Sergey Gusev.** From Kalman-Yakubovich-Popov Lemma To Hilbert's 17-th Problem and Back Again

Affiliation: Saint-Petersburg State University

Abstract: The brief survey of modern generalizations of the KYP lemma is presented. The close relation between the KYP lemma and the statement of Hilbert's 17-th problem is established. It is shown that the constructive solution of Hilbert's 17-th problem for strict inequalities can be obtained using parameter-dependent matrix-valued version of the KYP lemma. From the other hand, existence of SOS representations for positive rational functions can be used to prove the feasibility of KYP matrix inequality (the Yakubovich's statement of the KYP lemma) in the case, when instead of real numbers some other ordered fields are used. In particular, if the matrices in formulation of the KYP lemma have rational coefficients then there is a solution of the non-strict KYP inequality with rational coefficients, while the rational solution of the corresponding algebraic Riccati equation does not need to exist.

Walking City Tour or Hermitage Tour (depending on the weather), 15:30-18:30

Welcome reception, 19:00-21:00

Tuesday September 20, 2011

Regular Session III, 09:30-10:50

09:30-09:50 **Michael Khlebnikov, Boris Polyak.** Design of linear dynamical output feedback controller for rejection of persistent disturbances

Affiliation: Institute of Control Sciences V.A. Trapeznikov Academy of Sciences

Abstract: The problem of rejection of nonrandom bounded exogenous disturbances (also known as peak-to-peak gain minimization) has the long history. It is the subject of l_1-optimization theory. However, l_1-optimization technique often leads to high-dimensional

controllers and is hard to implement in the continuous-time case.

A natural way to overcome these difficulties is to appeal to the invariant sets ideology, in order to reduce complexity and attain the control objectives. Among various possible \shapes" of invariant sets utilized in the research areas above, ellipsoids should be distinguished because of their simple structure and direct connection to the quadratic Lyapunov functions approach.

Moreover, the ellipsoidal description allows to exploit the powerful machinery of linear matrix inequalities and semidefinite programming as a technical solution tool.

In the talk we address the above mentioned problem by use of the linear dynamical output feedback full-order controller. Up to the authors' knowledge, the design of general dynamical controller for rejection of L_∞-bounded disturbances remained an open problem.

The efficiency of the approach is illustrated via the real-life control problem for the gyroplatform. The approach is also applicable to discrete-time systems and to robust problem formulations.

09:50-10:10 **Martin Enqvist.** Invertible time series and closed-loop identification of nonlinear systems

Affiliation: Linkoping University

Abstract: System identification methods can be used to estimate a model of an unknown system from experimental data. The conditions under which the dataset has been collected are crucial for the performance of any identification method. For example, the fact whether the input and output measurements have been collected under open-loop or closed-loop conditions is important since closed-loop data might lead to biased model estimates in some cases. The case of closed-loop identification of a linear system with a linear controller has been studied in detail in many earlier publications. However, there are several open problems concerning the cases when there are nonlinearities in either the system or the controller or in both. Here, the importance of invertible time series for closed-loop identification of nonlinear systems will be discussed. For example, it turns out that the invertibility of the reference signal is important when a linear system is estimated from closed-loop data where a nonlinear controller has been used. Furthermore, the invertibility of the noise signal is also critical for the direct prediction-error approach to work for a nonlinear system in closed loop.

10:10-10:30 **Andrey Polyakov.** Nonlinear Feedback Design for Fixed-Time Stabilization of Linear Plants

Affiliation: Institute of Control Sciences V.A. Trapeznikov Academy of Sciences

Abstract: The problems of finite-time stability and stabilization have often been a subject of research. This paper studies the new form of the global finitetime stability, which is related to possible predefining of guaranteed convergence (settling) time independently on initial conditions. This paper calls the corresponding stability form by fixed-time stability. Two control algorithms for uncertain linear plants are developed. The first one provides global asymptotic stability of the closed-loop system and allows to adjust a guaranteed convergence time of system trajectories into selected neighborhood of the origin independently on domain of initial system states (fixed-time attractivity). And the second algorithm guarantees global finite-time stability of the closed-loop system with globally bounded settling-time function (fixed-time stability). The design procedures essentially use block reduction principles and finite-time attractivity properties for polynomial feedbacks. The control design algorithms are presented for both single-input and multi-input control systems. Theoretical results are supported by numerical simulations.

10:30-10:50 **Egi Hidayat.** Laguerre domain identification of continuous linear time delay systems from impulse response data

Affiliation: Uppsala University

Abstract: A method for Laguerre domain identification of continuous time delay systems from impulse response data is proposed. Linear time-invariant systems resulting from cascading finite-dimensional dynamics with pure time delays are considered. A state-space description of the time delay system in the Laguerre shift operator is obtained. Subspace identification is utilized for estimation of finite-dimensional dynamics. An application to blind identification of a mathematical model of an endocrine system with pulsatile regulation is also provided.

Coffee Break, 10:50-11:10

Regular Session IV, 11:10-12:30

11:10-11:30 **Bengt Lennartson and Oskar Wigström (Sweden), Alberto Vergnano (Italy).** High level scheduling of energy optimal trajectories applied to robot coordination

Affiliation: Chalmers University of Technology, University of Modena and Reggio Emilia

Abstract: The reduction of energy consumptions is addressed with great efforts in manufacturing industry. A previously presented method for robotic system scheduling, which exploits variable execution time for the individual robot operations, has shown promising results for energy consumption optimization. The method introduces linear time scaling of the trajectories to slow down the manipulators movements. This paper improves the scheduling method by generating energy optimal trajectories using dynamic time scaling. Dynamic programming can be applied to an existing trajectory and generate a new energy optimal trajectory that follows the same path but in a different execution time frame. With the new method, it is possible to solve the optimization problem for a range of execution times in one simulation run only. A case study of a cell comprised of four six-link manipulators is presented, in which energy optimal dynamic time scaling is compared to linear time scaling. The results show that the energy consumption can be significantly decreased by the suggested optimization procedure.

11:30-11:50 **Alexey Bobtsov, Anton Pyrkin**. Simple Adaptive Output Control for Nonlinear Systems with Time-Delay

Affiliation: National Research University of Information Technologies, Mechanics and Optics

Abstract: This paper deals with the output stabilization of time-delay systems with sector-bounded nonlinearity. In this paper we will consider the problem of absolute stability for a class of time-delay systems which can be represented as a feedback connection of a linear dynamical system with unknown parameters and an uncertainty nonlinearity satisfying a sector constraint. For a class of output control algorithms a controller providing output exponential stability of equilibrium position is designed.

11:50-12:10 **Andrey Barabanov.** Fast identification of the voiced speech signal

Affiliation: Saint-Petersburg State University

Abstract: A multiple harmonic model is a good approximation to a voiced speech signal. It

is nonlinear in Fundamental frequency and linear in amplitudes and phases. A fast algorithm for the LS identification is proposed. It is based on the recent achievements in nonstationary modelling of a speech signal and on the "bell" approximations of the digital harmonic spectrum.

12:10-12:30 **Anders Robertsson.** On Optimal Paths, Tracking and Constraint-based control for Robotic applications

Affiliation: Lund University

Abstract: Recently, the formulation of virtual holonomic constraints has been used for design of regulators for achieving stable oscillatory motions of under-actuated systems. The same underlying equations also shows up for solving a minimum time optimization problem; traversing a given path with a robot manipulator in as short time possible under input constraints. Different problem reformulations are discussed together with some suggested methods of finding optimal solutions. We also discuss the use of these optimal solutions for tracking control of industrial robots. A control structure, in which the optimal trajectories are essential, are used ensure robustness for model errors and disturbances.

Lunch, 12:30-14:00

Regular Session V, 14:00-15:20

14:00-14:20 **Leonid Freidovich, Anton Shiriaev.** On global robust stabilization of the 3-state Moore-Greitzer model

Affiliation: Umeå University

Abstract: The well-known nonlinear Moore-Greitzer model is commonly used for approximating dynamics of deviations of the flow and pressure variables in axial compressors from their nominal steady states. The model is a nonlinear connection of a two-dimensional surge subsystem with a control input and a cubic nonlinearity and of a scalar differential equation describing stall dynamics, linearization of which is critically stable.

Design of a robust feedback stabilizing regulator with a large region of attraction for this system, that is implementable in practical settings, is an important for various applications but challenging task. We present a parameterized family of feedback controllers and sufficient conditions on the coefficients that ensure robust global asymptotic stability. The problem is solved as follows. First, a family of robust globally stabilizing feedback control laws for the surge subsystem is designed based on quadratic constraints satisfied by the cubic nonlinearity assuming that the stall variable is zero. Examples of valid choices for the control coefficients are given for stabilizing control laws with and without integral action for a particular set of the system's parameters. Second, to ensure that the overall closed-loop system with nontrivial stall dynamics has the unique equilibrium at the origin, a subfamily of control laws with integral action is singled out. Finally, we show that every control law in this subfamily achieves global asymptotic stability. Our proof exploits integrability and other special properties of the stall dynamics, as well as analysis of omega-limit sets, introduction of a fictitious integral quadratic constraint to obtain a non-increasing along the solutions quadratic function based on the Frequency Theorem, and computation of dynamics restricted to the central manifold for verification of local asymptotic stability. Numerical simulations are done to observe performance of a closed-loop system with a designed feedback control law.

14:20-14:40 **Anton Proskurnikov.** Absolute stability methods for consensus in nonlinear networks

Affiliation: Institute of Problems in Mechanical Engineering of Russian Academy of Sciences

Abstract: Problems of controlled synchronization referred also as consensus or agreement problems are of great interest nowadays since a number of biological and physical phenomena as well as engineering methods are based on the synchronization mechanisms.

Consensus algorithms have applications in computer science and distributed computations, phase-locked loops design, load balancing in power systems, modeling of biological populations performance, controlling of mobile robots and UAV groups etc.

Most of existing results for consensus algorithms convergence deal with linearly coupled networks of agents, assuming the agents to be governed with low-order models. The paper will be devoted to results of new type that are based on the absolute stability theory and are applicable to networks of agents having arbitrarty dimensions with nonlinear and possibly uncertain couplings, satisfying the sector conditions. The network topology may be switching and is assumed to satisfy some

connectivity assumptions only.

We obtain the frequency-domain conditions for consensus that may be considered as extensions of the well-known stability criteria for Lurie systems (circle criterion etc.) to the case of networked multiagent systems.

14:40-15:00 **Alexander Medvedev.** Dynamical systems approach to endocrine regulation

Affiliation: Uppsala University

Abstract: Hormones are signaling molecules, acting as chemical messengers from one cell (or a group of cells) to another, and are produced by nearly every organ and tissue type in a multi-cellular organism. Hormonal (endocrine) regulation is seen as a complex dynamic biological system where hormones, often represented by their serum concentrations, interact via numerous feedback and feedforward relationships.

Endocrine glands secrete their product (hormones) either in continuous (basal) or pulsatile (nonbasal) manner. The pulsatile hormone secretion generally stems from the pulse dynamics of neurons. This requires both continuous and discrete dynamical blocks to be used in mathematical modeling of endocrine regulation. Hormone concentration pulses are modulated in amplitude and frequency with both characteristics imparting biological effect. Theory of pulse-modulated systems comes in handy in analysis of biological phenomena arising in endocrine systems with non-basal hormone secretion.

A recently proposed parsimonious mathematical model of non-basal hormone secretion is composed of a linear block describing the kinetics of the involved hormones in a closed loop with an amplitude and frequency pulse-modulated feedback. This hybrid model displays a great variety of nonlinear dynamical phenomena, including finite and infinite sequences of direct and reverse period-doubling cascades as well as a period-doubling transition to chaos. Bifurcation analysis proves the model to be monostable with bifurcation curves in the form of closed contours. A limited repertoire of dynamical behaviors is otherwise an inherent limitation of smooth continuous low-order models.

In this talk, an overview of mathematical properties of the model under consideration will be given. Current and perspective applications of hybrid models to endocrine systems will be presented and exemplified. Open problems pertaining to state and parameter estimation in mathematical models of endocrine regulation will be as well formulated and

discussed.

15:00-15:20 **Anton Selivanov.** Adaptive synchronization of networks with delayed couplings

Affiliation: Saint-Petersburg State University

Abstract: Passification based adaptive synchronization method for decentralized control of dynamical networks applied to the networks with delayed couplings. In the contrast to the existing papers the case of incomplete control and incomplete measurements is examined (both number of inputs and the number of outputs are less than the number of the state variables). Delay independent synchronization conditions are provided. The solution is based on passification in combination with using Lyapunov-Krasovskii functional.

Coffee Break, 15:20-15:40

Regular Session VI, 15:40-17:00

15:40-16:00 **Margarida Martins da Silva.** Prediction error identification algorithms for anesthesia-related Wiener models

Affiliation: Uppsala University

Abstract: Patient modeling and identification are decisive steps to achieve successful control strategies for automatic drug dosing in patients subject to anesthesia. This idea goes in line with the parsimony principle of system identification theory and is strongly correlated with the main ideas of this work. The poor excitatory profile of the anesthetic dosages that are administered during surgical procedures (considered as the system inputs) together with the limited amount of output data that is usually available during an anesthesia case pose difficulties to the identification of the high number of parameters present in the standard models commonly used to describe the effect of anesthetics in humans.

The first contribution of this work is hence to present prediction error identification algorithms for recently published minimally parameterized Wiener models for the neuromuscular blockade (NMB) and the depth of anesthesia (DoA) [5, 4]. The two parameters of a SISO Wiener model describing the effect of the muscle relaxant rocuronium in the NMB [2] are identified. Regarding the DoA, the four parameters of a MISO Wiener model describing the joint effect of the hypnotic propofol and the opioid

remifentanil in the Bispectral Index [3] are also identified. The proposed algorithms are general for cases where the relationship between the amount of drug that is given to a patient and the observed effect is modeled by a Wiener structure [6]: a linear mixing dynamics of the drug followed by a static nonlinearity describing the measured effect. This is the case of most Pharmacokinetic/Pharmacodynamic (PK/PD) cascaded models [1]. The second contribution is to exemplify the performance of the proposed algorithms in two databases of real records collected in the surgery room.

The results show that the predicted signals using the parameter estimates given by the identification algorithm capture the main behavior of the NMB and DoA real signals, discarding the noise present in the real measurements, as desired. The minimally parameterized models are hence expected to provide even better predictions of the system when used in recursive identification algorithms. The knowledge of the models structures and parameters taken from these offline experiments will be very useful for the development of those recursive algorithms, suitable to be incorporated in real-time control platforms for automatic drug dosing in patients undergoing anesthesia.

References

[1] H. Derendorf and B. Meibohm. Modeling of Pharmacokinetic/Pharmacodynamic (PK/PD) relationships: concepts and perspectives. *Pharmaceutical Research*, 16:176–185, 1999.

[2] T. Mendonëca, J.M. Lemos, H. Magalh˜aes, P. Rocha, and S. Esteves. Drug delivery for neuromuscular blockade with supervised multimodel adaptive control. *IEEE Transactions on Control Systems Technology*, 17(6):1237 –1244, nov. 2009.

[3] J. Sigl and N. Chamoun. An introduction to bispectral analysis for the electroencephalogram. *Journal of Clinical Monitoring and Computing*, 10:392–404, 1994.

[4] M. M. Silva, T. Mendonëca, and T. Wigren. Online nonlinear identification of the effect of drugs in anaesthesia using a minimal parameterization and BIS measurements. In *Proc. American Control Conference (ACC'10)*, pages 4379–4384, Baltimore, USA, June 2010.

[5] M. M. Silva, T. Wigren, and T. Mendonëca. Nonlinear identification of a minimal neuromuscular blockade model in anesthesia. *IEEE Transactions on Control Systems Technology*, 2011.

[6] T. Wigren. Recursive prediction error identification method using the nonlinear Wiener

model. *Automatica*, 29(4):1011–1025, 1993.

16:00-16:20 **Pavel Tochilin.** Output feedback control of the oscillating system under set-membership uncertainties

Affiliation: Lomonosov Moscow State University

Abstract: The paper considers the problem of controlling the linear oscillating system with disturbances in the dynamics on the basis of available on-line observations under noisy measurements. There are hard bounds on the noise with no additional information (for example any probabilistic model). The problem is to drive the system's trajectory into the prescribed neighborhood of the given target set despite the unknown disturbances, within a finite time horizon. As it is acknowledged the overall problem is a combination of two subproblems: guaranteed state estimation and feedback control under set-membership uncertainties. For the considered linear case both problems are finite-dimensional and they may be solved numerically. A computational procedure for solving the problem is described in the paper. It is based on the use of the ellipsoidal calculus techniques. This approach allows to calculate on-line feedback control for any admissible disturbances: probabilistic or determinate.

Another problem considered in the paper is to track the trajectory of one oscillating subsystem with the help of another subsystem's trajectory. The second subsystem contains control parameters. Output feedback control uses incomplete, noisy information about the difference between current positions of the subsystems. It's also necessary to provide the feedback control law which holds the trajectory of the second subsystem inside prescribed neighborhood of the first subsystem's trajectory. The problem can be solved by introducing new variables and reducing it to the preceding problem. Some numerical methods based on ellipsoidal calculus are also considered.

16:20-16:40 **Giacomo Como.** Stability analysis of transportation networks with multiscale driver decisions

Affiliation: Lund University

Abstract: Stability of Wardrop equilibria is analyzed for dynamical transportation networks in which the drivers' route choices are influenced by information at multiple temporal and spatial scales. The considered model involves a continuum of indistinguishable drivers

commuting between a common origin/destination pair in an acyclic transportation network. The drivers' route choices are affected by their, relatively infrequent, perturbed best responses to global information about the current network congestion levels, as well as their instantaneous local observation of the immediate surroundings as they transit through the network. A novel model is proposed for the drivers' route choice behavior, exhibiting local consistency with their preference toward globally less congested paths as well as myopic decisions in favor of locally less congested paths. The simultaneous evolution of the traffic congestion on the network and of the aggregate path preference is modeled by a system of coupled ordinary differential equations. The main result shows that, if the frequency of updates of path preferences is sufficiently small as compared to the frequency of the traffic flow dynamics, then the state of the transportation network ultimately approaches a neighborhood of the Wardrop equilibrium. The proposed analysis combines techniques from singular perturbation theory, evolutionary game theory, and cooperative dynamical systems.

16:40-17:00 **Alexander Fradkov.** Static Output Feedback Synchronization of Dynamical Networks

Affiliation: Institute of Problems in Mechanical Engineering of Russian Academy of Sciences

Abstract: A new solution to the static output feedback synchronization problem for a network of identical linear systems is proposed. Using passification method parameters of static output feedback controller and conditions of synchronization in directed networks consisting of linear agents are obtained for both balanced and unbalanced directed communication graphs under conditions of incomplete control. Sufficient synchronization conditions are established by means of passification method and Agaev-Chebotarev theorem.

Technical tour: Museum of Optics, 17.00-18.30

Banquet, 19:00-22:00