# List of Abstracts

## Monday, 5 July

### Opening Ceremony

**Room 1**

08.40 – 09.00

Welcome Addresses

### Plenary Lecture

**Room 1**

***Chair:*** *Giorgio Picci*

09.00 – 10.00

Models of Real-World Networks: Inhomogeneous Random Graphs and Convergent Graph Sequences
*Béla Bollobás*

### Stochastic Model Predictive Control
*(Invited Session)*

**Room 1**

***Organizers:*** *Peter Hokayem, Debasish Chatterjee, John Lygeros*
***Chair:*** *Peter Hokayem*

10.30 – 11.00

Stochastic Tube MPC with State Estimation
*Mark Cannon, Qifeng Cheng, Basil Kouvaritakis, Saša V. Raković*

***Abstract*–An output feedback Model Predictive Control (MPC) strategy for linear systems with additive stochastic disturbances and probabilistic constraints is proposed. Given the probability distributions of the disturbance input, the measurement noise and the initial state estimation error, the distributions of future realizations of the constrained variables are predicted using the dynamics of the plant and a linear state estimator. From these distributions, a set of deterministic constraints are computed for the predictions of a nominal model. The constraints are incorporated in a receding horizon optimization of an expected quadratic cost, which is formulated as a quadratic program. The constraints are constructed so as to provide a guarantee of recursive feasibility, and the closed loop system is stable in a mean-square sense.**

11.00 – 11.30

Constrained Control Design – A Simulation-Based Scenario Approach
*Maria Prandini, Marco C. Campi*

***Abstract*–This paper deals with constrained control design for linear systems affected by stochastic disturbances. The goal is to optimize the control performance while guaranteeing that the constraints are satisfied for most of the disturbance realizations, that is with probability $1-\epsilon$. In mathematical terms, this amounts to solve a "chance-constrained" optimization program and we introduce here a randomized approach to this problem that builds on certain recent results in robust convex optimization.**

11.30 – 12.00

Stable Markov Decision Processes Using Simulation Based Predictive Control
*Zhe Yang, Nikolas Kantas, Andrea Lecchini-Visintini, Jan M. Maciejowski*

***Abstract*–In this paper we investigate the use of Model Predictive control for Markov Decision Processes under weak assumptions. We provide conditions for stability based on optimality of a specific class of cost functions. These results are useful from both a theoretical and computational perspective. When nonlinear non-Gaussian models for general state spaces are considered, the absence of analytical tools makes the use of simulation based methods necessary. Popular simulation based methods like stochastic programming and Markov Chain Monte Carlo can be used to provide open loop estimates of the optimisers. With this in mind we provide conditions under which such an approach would yield stable Markov Decision Processes.**

12.00 – 12.30

Stable Stochastic Receding Horizon Control of Linear Systems with Bounded Control Inputs
*Peter Hokayem, Debasish Chatterjee, Federico Ramponi, Georgios Chaloulos, John Lygeros*

***Abstract*–We address stability of receding horizon control for stochastic linear systems with additive noise and bounded control authority. We construct tractable and recursively feasible receding horizon control policies that ensure a mean-square bounded system in closed-loop if the noise has bounded forthorder moment, the unexcited system is stabilizable, the system matrix A is Lyapunov stable, and there is large enough control authority.**

### Information and Markov Dynamics
*(Regular Session)*

**Room 2**

***Chair:*** *Zsolt Talata*

10.30 – 11.00

Finite Memory Estimation of Infinite Memory Processes
*Imre Csiszár, Zsolt Talata*

***Abstract*— Stationary ergodic processes with finite alphabets are approximated by finite memory processes based on an $n$-length realization of the process. Under the assumptions of summable continuity rate and non-nullness, a rate of convergence in $\bar{d}$-distance is obtained, with explicit constants. Asymptotically, as $n \to \infty$, the result is near the optimum.**

11.00 – 11.30

The Information Inequality on Function Spaces Given a Singular Information Matrix
*Tzvetan Ivanov, Pierre-Antoine Absil, Michel Gevers*

***Abstract*–In this work we extend the scope of the classical Cramér-Rao lower bound, or information inequality, from Euclidean to function spaces. In other words we derive a tight lower bound on the autocovariance function of a function estimator. We do this in the context of system identification. Two key elements of system identification are experiment design and model selection. The novel information inequality on function spaces is important for model selection because it allows the user to compare estimators using different model structures. We provide a consistent treatment of the**

case where the Fisher information matrix is singular. This makes it possible to take into account that in optimal experiment design one tries to mask those parts of the system non-identifiable, which are irrelevant for the application.

11.30 – 12.00

Minimum Relative Entropy State Transitions in Linear Stochastic Systems: the Continuous Time Case

*Igor G. Vladimirov, Ian R. Petersen*

***Abstract*–This paper develops a dissipativity theory for dynamical systems governed by linear Itô stochastic differential equations driven by random noise with an uncertain drift. The deviation of the noise from a standard Wiener process in the nominal model is quantified by relative entropy. The paper discusses a dissipation inequality for the noise relative entropy supply. The problem of minimizing the supply required to drive the system between given Gaussian state distributions over a specified time horizon is considered. This problem, known in the literature as the Schrödinger bridge, was treated previously in the context of reciprocal processes. The paper obtains a closedform smooth solution to a Hamilton-Jacobi equation for the minimum required relative entropy supply by using nonlinear algebraic techniques.**

12.00 – 12.30

Deconvolution of Quantized-Input Linear Systems: analysis via Markov Processes of a Low-Complexity Algorithm

*Sophie M. Fosson, Paolo Tilli*

***Abstract*–This paper is concerned with the problem of the deconvolution, which consists in recovering the unknown input of a linear system from a noisy version of the output. The case of a system with quantized input is considered and a low-complexity algorithm, derived from decoding techniques, is introduced to tackle it. The performance of such algorithm is analytically evaluated through the Theory of Markov Processes. In this framework, results are shown which prove the uniqueness of an invariant probability measure of a Markov Process, even in case of non-standard state space. Finally, the theoretic issues are compared with simulations' outcomes.**

## Observers

*(Regular Session)*

**Room 3**

***Chair:*** *José Mario Araújo*

10.30 – 11.00

Conditioned-Invariant Polyhedral Sets for Observers with Error Limitation in Discrete-Time Descriptor Systems

*José Mario Araújo, Péricles Rezende Barros, Carlos Eduardo Trabuco Dórea*

***Abstract*–This works aims to establish a characterization of conditioned-invariant polyhedral sets applied in the context of state estimation in linear discrete-time descriptor systems. It is shown that, assuming causality, the existing conditions for linear systems in the standard form can be extended to descriptor ones, by rewriting the state equation in a suitable form. To this end, a specific descriptor structure for the observer is proposed, whereby limitation of the estimation error can be achieved by the computation of an as small as possible conditioned invariant polyhedron that contains the set of possible initial errors, which is also characterized, together with the corresponding output injection. The effectiveness of methodology is then illustrated by numerical examples.**

11.00 – 11.30

Output Feedback Observers and Control under Non-Gaussian Types of Noise

*Alexander B. Kurzhanski, Irina A. Digailova*

***Abstract*–The recent applied motivations for mathematical problems on systems and control emphasize increased interest in feedback control under realistic system output information on the basis of observations corrupted by various types of disturbances (noise). The present text deals with several situations of such type where the noise is confined not only to Gaussian descriptions but also allows nonprobabilistic interpretation. The text is restricted to systems with original linear structure which, after being subjected to feedback control, may turn out to become nonlinear. Indicated here are some concise descriptions for an array of problems and results with detailed solution versions to appear. Beginning with description of connections between stochastic Gaussian and set-membership bounding approaches, it further proceeds with problems on output feedback control under control dependent input stochastic noise additively combined with unknown but bounded disturbances. This produces problems under statistical uncertainty. The next item is a discussion of observers under discrete-time measurements that occur at random instants of time subjected to a Poisson distribution. Conditions on system properties and measurement noise are indicated when the produced solution is asymptotically consistent.**

11.30 – 12.00

Internal Observers for Linear Systems with Time-Varying Delays

*Mustapha Ait Rami, Jens Jordan, Michael Schönlein*

***Abstract*–This paper considers linear observed systems with time-varying delays, where the state as well as the observation of the state is subject to delays. It is assumed that the delays are unknown but stay below a certain bound. Similar to the case of uncertainties in the systems parameters we aim to derive upper and lower estimates for the state of the system under consideration. A pair of estimators providing such bounds is called an interval observer. In particular, the case where the estimators converge asymptotically is of notable interest. In this case the interval observer is said to be convergent. In this paper we derive necessary and sufficient conditions for the existence of a convergent interval observer for linear observed systems with time-varying bounded delays.**

## Algebraic Systems Theory, Behaviors, and Codes: Stabilization and Interconnection

*(Invited Session)*

**Room 4**

***Organizers:*** *Eva Zerz, Heide Glüsing-Lürssen*
***Chair:*** *Eva Zerz*

10.30 – 11.00

A Behavioral Approach to Modeling Electrical Circuits

*Jan C. Willems*

***Abstract*–The aim of this contribution is to present a hierarchical way of modeling electrical circuits.**

**A circuit is a device that interacts with its environment through wires, usually called terminals. Associated with each terminal there is a potential and a current. One can also start from the voltage difference between the terminals, but it can be shown that Kirchhoff's voltage law implies that the potential description is equivalent. We view the modeling as proceeding in two steps, first modeling an individual circuit, followed by modeling the interconnection of circuits.**

First we outline a method of obtaining a model of an individual circuit. Assume that the circuit consists of elements with two-terminal ports, as R, L, C's, transformers, and gyrators. Modeling aims at specifying the behavior of the terminal potential/current vector from the circuit architecture and the values of the circuit elements. We define the architecture of the circuit as a graph with leaves, with ports in the edges, connectors in the vertices, and external terminals in the leaves. We show how in the linear case, this leads to a systematic way to obtain the circuit behavior by introducing as latent variables the potentials of the vertices and the currents in the branches.

Next we turn to the interconnection of multi-terminal. The architecture of a configuration is formalized as a graph with leaves, with the vertices corresponding to subcircuits, the edges to the connected terminals of the subcircuits, and the leaves to external terminals. The model then follows from the behavior of the subcircuits in the vertices and the interconnection laws for the edges. This architecture is hierarchical since the subcircuits can in turn be interconnected circuits in their own right.

There is a striking difference between the modeling procedure of the individual circuits and the modeling of the interconnection of circuits. In the former case, the elements are in the edges and the vertices correspond to the connections. In the latter case, the elements (the subcircuits) are in the vertices and the edges correspond to the connections.

11.00 – 11.30

The Design and Parametrization of Stabilizing Feedback Compensators via Injective Cogenerator Quotient Signal Modules
*Ingrid Blumthaler, Ulrich Oberst*

*Abstract*—The design and parametrization of stabilizing feedback compensators which realize various goals like tracking, disturbance rejection, decoupling, model matching and others belong to the most important and difficult tasks of control engineering and have therefore been treated by many prominent researchers and in many textbooks, the systems being generally described by their transfer matrices or by Rosenbrock equations. Our approach to these important problems uses, in addition to the ideas of our predecessors, a new mathematical technique and is distinguished by the following features:

1) The plant, the compensator and the full feedback system are given as input/output behaviors. We study the full feedback behavior and especially its autonomous part and not only its transfer matrix or an induced manifest controlled behavior (like Willems et al.).
2) We simultaneously treat continuous and discrete systems and different notions of stability, for instance asymptotic and dead-beat stability, which are defined by multiplicatively closed sets $T$ of $T$-stable polynomials and their quotient rings of $T$-stable rational functions.
3) We solve the problem of pole placement or spectral assignability for the complete feedback behavior.
4) We use an injective cogenerator signal module $\mathcal{F}$ over the polynomial algebra like all standard signal spaces and its quotient module $\mathcal{F}_T$ which is an injective cogenerator over the ring of stable rational functions and induces a categorical duality between finitely generated modules over this ring and $\mathcal{F}_T$-behaviors which represent the essential part of the behaviors in stability problems. The new duality technique enables very short and conceptual proofs both of standard results and also of sharper new ones. For instance, under the assumption of $T$-stabilizability we parametrize all tracking stabilizing compensators of a *not necessarily proper* plant such that both the feedback behavior and the compensator itself are proper. The first property ensures the absence of impulsive solutions in the continuous case, and the second property enables the realization of the compensator by Kalman equations or elementary building blocks. We notice that every behavior admits an input/output decomposition with proper transfer matrix, but that most of these decompositions do not have this property, and therefore we do not assume the properness of the plant.

11.30 – 12.00

Control of 2D Behaviors by Partial Interconnection
*Paula Rocha, Diego Napp Avelli*

*Abstract*–In this paper we study the stability of two dimensional (2D) behaviors with two types of variables: the variables that we are interested to control (the to-be-controlled variables) and the variables on which we are allowed to enforce restrictions (the control variables). We derive conditions for the stabilization of the to-be-controlled variables by regular partial interconnection, i.e., by imposing non-redundant additional restrictions to the control variables.

12.00 – 12.30

Robustly Stable Multivariate Polynomials
*Martin Scheicher*

*Abstract*— We consider stability and robust stability of polynomials with respect to a given arbitrary disjoint decomposition $\mathbb{C}^n = \Gamma \uplus \Lambda$. The polynomial is called stable if it has no zeros in the region of instability $\Lambda$ and robustly stable if it is stable and remains so under small variations of its coefficients. Inspired by the article *Robust stability of multivariate polynomials. Part 1: Small coefficient perturbations* by V. L. Kharitonov and J. A. Torres-Muñoz (Multidimens. Systems Signal Process., 10(1):21–32, 1999), we generalise some of their results to arbitrary stability decompositions and develop some fundamental results on robustly stable polynomials. Among them is a characterisation of robust stability in terms of the stability of several other polynomials, which yields a test for robust stability based on stability tests. Finally, we consider the special situation that the region of instability is a Cartesian product and recover some results for the special situations of linear partial differential resp. difference equation with constant coefficients.

## Real Algebraic Geometry and Applications – 1
*(Invited Session)*

**Room 6**

***Organizers:*** *William J. Helton, Pablo Parrilo*
***Chair:*** *William J. Helton*

10.30 – 11.00

Input-Output Systems Analysis Using Sum Of Squares Programming: a Decomposition Approach
*James Anderson, Antonis Papachristodoulou*

*Abstract*–A method for estimating the $L_2$ gain of a nonlinear system using sum of squares (SOS) programming and dynamical system decomposition is presented. Typically SOS approaches to systems analysis are only computationally tractable for systems of a modest state dimension comprising of low order vector fields. We present a dynamical system decomposition approach that extends the class of systems that the $L_2$ gain can be estimated for using SOS methods to include those of large state dimension with high vector field degree.

11.00 – 11.30

The Grothendieck Problem With Rank Constraint
*Jop Briët, Fernando Mário De Oliveira Filho, Frank Vallentin*

*Abstract*–Finding a sparse/low rank solution in linear/semidefinite programming has many important applications, e.g. combinatorial optimization, compressed sensing, geometric embedding, sensor network localization. Here we consider one of the most basic problems involving semidefinite programs with rank constraints: the Grothendieck problem with rank-k-constraint. It contains the MAX CUT problem as a special case when k = 1. We perform a complexity analysis of the problem by designing an approximation

**algorithm which is asymptotically optimal if one assumes the unique games conjecture.**

11.30 – 12.00

Programmable Antenna Design Using Convex Optimization
*Javad Lavaei, Aydin Babakhani, Ali Hajimiri, John C. Doyle*

***Abstract*— This work presents an application of convex optimization and algebraic geometry in devising secure, power-efficient, beam-steerable, and on-chip transmission systems for wireless networks. First, we introduce a *passively controllable smart (PCS) antenna system* that can be programmed to generate different radiation patterns in far field by adjusting its variable passive controller at every signal transmission. To study the programming capability of a PCS antenna system, we consider a PCS antenna transmitting data in $z$ directions, where some voltages $v_1, v_2, ..., v_z$ are induced in different directions in far field. The objective of this paper is to study the set of all feasible vectors $(v_1, v_2, ..., v_z)$ that can be generated by a passive control of the PCS antenna system. To this end, it is shown that all feasible vectors $(v_1, v_2, ..., v_z)$ form a convex semi-algebraic set parameterized by a linear matrix inequality (LMI). Later on, this LMI condition is further studied and it is proven that the geometry of the set of all feasible voltages $(v_1, v_2, ..., v_z)$ is simply an ellipsoid. This significant result makes it possible to compute the feasibility set online to decide how the PCS antenna must be programmed for either directional or simultaneous data transmission. Unlike the existing smart antennas whose programming leads to an NP-hard problem or are made of many active elements, the PCS antenna proposed in the present work has a low-complex programming capability and consists of only one active element.**

12.00 – 12.30

On the Real Multidimensional Rational *K*-Moment Problem
*Jaka Cimprič, Murray Marshall, Tim Netzer*

***Abstract*— We present a solution to the real multidimensional rational $K$-moment problem, where $K$ is defined by finitely many polynomial inequalities. More precisely, let $S$ be a finite set of real polynomials in $\underline{X} = (X_1, \ldots, X_n)$ such that the corresponding basic closed semialgebraic set $K_S$ is nonempty. Let $E = D^{-1}\mathbb{R}[\underline{X}]$ be a localization of the real polynomial algebra, and $T_S^E$ the preordering on $E$ generated by $S$. We show that every linear functional $L$ on $E$ such that $L(T_S^E) \geq 0$ is represented by a positive measure $\mu$ on a certain subset of $K_S$, provided $D$ contains an element that grows fast enough on $K_S$.**

## Graph Processes
*(Regular Session)*

**Room 7**

***Chair:*** *Thomas P. Cason*

10.30 – 11.00

A Unified Framework for Affine Local Graph Similarity
*Thomas P. Cason, Pierre-Antoine Absil, V.D. Blondel, Paul van Dooren*

***Abstract*–In this work, we review and classify several similarity measures on undirected graphs. We show that these measures can be rewritten in terms of fixed points of a scaled affine transformation. Finally, we propose a novel definition that avoids undesirable degeneracy of the similarity matrix.**

11.00 – 11.30

Vulnerability Analysis for Complex Networks Using Aggressive Abstraction
*Richard Colbaugh, Kristin Glass*

***Abstract*–Large, complex networks are ubiquitous in nature and society, and there is great interest in developing rigorous, scalable methods for identifying and characterizing their vulnerabilities. This paper presents an approach for analyzing the dynamics of complex networks in which the network of interest is first abstracted to a much simpler, but mathematically equivalent, representation, the required analysis is performed on the abstraction, and analytic conclusions are then mapped back to the original network and interpreted there. We begin by identifying a broad and important class of complex networks which admit vulnerability-preserving, finite state abstractions, and develop efficient algorithms for computing these abstractions. We then propose a vulnerability analysis methodology which combines these finite state abstractions with formal analytics from theoretical computer science to yield a comprehensive vulnerability analysis process for networks of realworld scale and complexity. The potential of the proposed approach is illustrated with a case study involving a realistic electric power grid model and also with brief discussions of biological and social network examples.**

11.30 – 12.00

Analysis of Complex Networks
*Angel Garrido*

***Abstract*–Our paper analyzes some new lines to advance on quickly evolving concepts, the so-called Complex Networks, represented by graphs in general. It will be very necessary to analyze the mutual relationship between some different concepts and their corresponding measures, with very interesting applications, as the case may be of Symmetry or Entropy, and Clustering Coefficient, for example.**

12.00 – 12.30

Cost Optimisation of Electric Power Transmission Networks Using Steiner Tree Theory
*Kevin Prendergast, Doreen Thomas*

***Abstract*–This paper introduces a new approach to electricity transmission network planning, which optimises the network with respect to capital cost. The approach is limited to three terminals at this stage, but it does illustrate the basic building blocks of a cost optimised network of larger size. Optimisation is achieved by means of a weighted Steiner tree method, in which the weight of a transmission line is the per unit length cost function. The angle between two connected lines is found, such that for a smaller angle a star network connecting the three terminals is more cost effective.**

## Communication
*(Regular Session)*

**Room 8**

***Chair:*** *Doreen Thomas*

10.30 – 11.00

A New Algorithm for the Euclidean k-Bottleneck Steiner Problem
*Marcus Brazil, Charl Ras, Doreen Thomas*

***Abstract*–We consider the problem of adding a fixed number of relays to a WSN in order to minimise the length of the longest transmission edge. Since routing subnetworks are often trees we model the problem as a Euclidean k-bottleneck Steiner tree problem (k-BSTP). We then propose a new iterative approximation algorithm for the k-BSTP, based on an exact solution to the 1-BSTP, and compare our heuristic (via simulation) to the currently best performing heuristic in the literature, namely the minimum spanning tree heuristic (MSTH). We observe that our algorithm performs up to 8% better than MSTH on uniformly distributed node-sets.**

11.00 – 11.30

Delay-Based Connectivity of Wireless Networks
*Martin Haenggi*

***Abstract***–**Interference in wireless networks causes intricate dependencies between the formation of links. In current graph models of wireless networks, where vertices represent transceivers and edges represent links, such dependencies are not included. In this paper we propose a random geometric graph that explicitly captures the effect of interference. The graph connects nodes which can communicate with a certain maximum expected delay. We analyze some basic properties of the graph where nodes form a Poisson point process and use ALOHA as the channel access scheme.**

11.30 – 12.00

Covering Codes and Invariant Sets
*Emerson L. Monte Carmelo*

***Abstract***—**Let $c_q(n, R)$ denote the minimum cardinality of a subset $H$ in $\mathbb{F}_q^n$ such that every word in this space differs in at most $R$ coordinates from a multiple of a vector in $H$, where $q$ is a prime power. In order to explore the symmetries of such coverings, a few algebraic properties of invariant sets under certain translation are investigated. As an application, a new class of upper bounds on $c_q(n, R)$ is reported, extending a previous result by Mendes et al. Moreover, the new upper bound on the classical covering $K_q(qr, qr - r - 1) \leq 2q - 1$ for a prime power $q \geq r + 3$ is derived too, improving a bound by Östergård.**

12.00 – 12.30

Classification Results for Non-Mixed and Mixed Optimal Covering Codes: a Survey
*Gerzson Kéri*

***Abstract***–**A survey is given that comprises the known classification results on non-mixed and mixed optimal covering codes. Several new, so far unpublished results of the author are declared and proved as well. The generality of the specified classification results are quite different. The proof of the more or less general new results are mostly combinatorial. In contrast with the latter, computer-aided proofs are given for numerous individual cases. The individual (old and new) classification results are merged and summarized in a set of tables.**

## Piece-Wise Affine Systems
*(Regular Session)*

**Room 9**

***Chair:*** *Madalena Chaves*

10.30 – 11.00

Transition Probabilities for Piecewise Affine Models of Genetic Networks
*Madalena Chaves, Etienne Farcot, Jean-Luc Gouzé*

***Abstract***–**In the piecewise affine framework, trajectories evolve among hyperrectangles in the state space. A qualitative description of the dynamics - useful for models of genetic networks - can be obtained by viewing each hyperrectangle as a node in a discrete system, so that trajectories follow a path in a transition graph. In this paper, a probabilistic interpretation is given for the transition between two nodes A and B, based on the volume of the initial conditions on hyperrectangle A whose trajectories cross to B. In an example consisting of two intertwinned negative loops, this probabilistic interpretation is used to predict the most likely periodic orbit given a set of parameters, or to find parameters such that the system yields a desired periodic orbit with a high probability.**

11.00 – 11.30

Chaos via Two-Valued Interval Maps in a Piecewise Affine Model Example for Hysteresis
*Rudolf Csikja, Barnabás M. Garay, János Tóth*

***Abstract***–**A standard piecewise affine model of hysteresis in two dimensions is reconsidered. Periodic orbits without selfintersection are studied and, in terms of the two real parameters, their full bifurcation analysis is given. The main tool is a piecewise smooth, two-valued Poincaré mapping with only four points of discontinuities, the first return map with respect to the line connecting the two equilibria. Earlier, single-valued Poincaré mappings for the same model were associated with the switching lines and had an infinite number of discontinuities. The present paper ends with bifurcation curves responsible for larger/smaller supports of absolutely continuous invariant measures.**

11.30 – 12.00

Temporal Logic Control for Piecewise-Affine Hybrid Systems on Polytopes
*Luc Habets, Calin Belta*

***Abstract***–**In this paper, a method is proposed for the design of control laws for hybrid systems with continuous inputs. The objective is to influence their behavior in such a way that the discrete component of the closed-loop system satisfies a given condition, described by a temporal logic formula. For this purpose, a transition system is constructed, by abstracting from the continuous dynamics of the hybrid system. It is shown that a controller for this transition system, realizing the given control objective, corresponds to a controller for the original hybrid system, realizing the same objective, and vice versa.**

12.00 – 12.30

Observability Reduction of Piecewise-Affine Hybrid Systems
*Mihály Petreczky, Jan H. van Schuppen*

***Abstract***–**We present necessary conditions for observability of piecewise-affine hybrid systems. We also propose an observability reduction algorithm for transforming a piecewiseaffine hybrid system to a hybrid system of possibly smaller dimension which satisfies the formulated necessary condition for observability.**

## Advanced Linear Algebra – 1
*(Regular Session)*

**Room 10**

***Chair:*** *Rodolphe Sepulchre*

10.30 – 11.00

Rank-Preserving Geometric Means of Positive Semi-Definite Matrices
*Silvere Bonnabel, Rodolphe Sepulchre*

***Abstract***–**The generalization of the usual geometric mean of two positive numbers a and b to positive definite matrices A and B has attracted considerable attention since the seminal work of Ando, and finds an increasing number of applications in signal and image processing. Building upon some recent work of the authors, the present paper proposes a generalization of any geometric mean defined on the interior of the cone of positive definite matrices, that is, for full rank matrices, to a rankpreserving geometric mean defined on the boundary of the cone, that is, for fixed-rank positive semidefinite matrices. The work is motivated by signal processing (e.g. filtering) operations on low-rank approximations of positive definite matrices in highdimensional spaces. The paper will discuss the reasons why the proposed definition is sound and relevant in applications.**

11.00 – 11.30

Gauss Elimination without Pivoting for Positive Semidefinite Matrices and an Application to Sum of Squares Representations
*Carla Fidalgo*

***Abstract*— It is shown that Gauss elimination without pivoting is possible for positive semidefinite matrices. While we do not claim the method as numerically the most advisable, it allows to obtain sum of squares (sos) representations in a more direct way and with more theoretical insight, than by the usual text book proposals. The result extends a theorem attributed for definite quadratic forms to Lagrange and Beltrami and is useful as a finishing step in recent algorithms by Powers and Wörmann [PW] and Parillo [PSPP] to write polynomials $p \in \mathbb{R}[x] = \mathbb{R}[x_1, \ldots, x_n]$ as a sum of squares in $\mathbb{R}[x]$ when such a representation exists.**

11.30 – 12.00

Algorithm to Compute Minimal Nullspace Basis of a Polynomial Matrix
*Swanand R. Khare, Harish K. Pillai, Madhu N. Belur*

***Abstract*–In this paper we propose a numerical algorithm to compute the minimal nullspace basis of a univariate polynomial matrix of arbitrary size. In order to do so a sequence of structured matrices is obtained from the given polynomial matrix. The nullspace of the polynomial matrix can be computed from the nullspaces of these structured matrices.**

12.00 – 12.30

On the Minimum Rank of a Generalized Matrix Approximation Problem in the Maximum Singular Value Norm
*Kin Cheong Sou, Anders Rantzer*

***Abstract*–In this paper theoretical results regarding a generalized minimum rank matrix approximation problem in the maximum singular value norm are presented. Using the idea of projection, the considered problem can be shown to be equivalent to a classical minimum rank matrix approximation which can be solved efficiently using singular value decomposition. In addition, as long as the generalized problem is feasible, it is shown to have exactly the same optimal objective value as that of the classical problem. Certain comments and extensions of the presented theorem are included in the end of the paper.**

## Non-Linear Dynamics
*(Regular Session)*

**Room 11**

***Chair:*** *Luigi Fortuna*

10.30 – 11.00

Bergson's Time and Strange Attractors
*Arturo Buscarino, Luigi Fortuna, Mattia Frasca*

***Abstract*–In this work the recurrence times of strange chaotic attractors are studied in relation to Bergson's view on time. According to the thought of this philosopher, time is a continuous flow of unique states of the consciousness. We define quantitative parameters characterizing recurrence times in chaotic attractors and show how these can account for the Bergson's concept of time.**

11.00 – 11.30

Derived Cones to Reachable Sets of Semilinear Differential Inclusions
*Aurelian Cernea*

***Abstract*–We consider a semilinear differential inclusion and we prove that the reachable set of a certain variational inclusion is a derived cone in the sense of Hestenes to the reachable set of the semilinear differential inclusion. This result allows to obtain a sufficient condition for local controllability along a reference trajectory.**

11.30 – 12.00

Identification of Nonlinear Processes in Microfluidic Bubble Flow
*Florinda Schembri, Francesca Sapuppo, Luigi Fortuna, Maide Bucolo*

***Abstract*–An approach based on nonlinear dynamical systems theory is used in this work to identify the complex temporal patterns in air bubbles flow carried by water in a snake microfluidic channel with two inlets. Air and water were pumped in with periodic flow. Different experimental campaigns have been designed varying the frequency of the flow rate alternatively for the water and for the air and maintaining fixed the other fluid flow. Microfluidic bubble flows were optically acquired by means of a photodiode-based system and converted into time series. In relation to the input control parameters (flow rate, frequency), the diversity of bubbles' temporal dynamic patterns was identified through nonlinear methodologies. Relationships between nonlinear parameters, volume fraction of fluids and capillary number were found suggesting the chaotic behavior of the system. This work is a fundamental step toward the control of bubble based operations in microfluidics.**

12.00 – 12.30

Interconnection of Dirac Structures and Lagrange-Dirac Dynamical Systems
*Hiroaki Yoshimura, Henry Jacobs, Jerrold E. Marsden*

***Abstract*–In the paper, we develop an idea of interconnection of Dirac structures and their associated Lagrange- Dirac dynamical systems. First, we briefly review the Lagrange- Dirac dynamical systems (namely, implicit Lagrangian systems) associated to induced Dirac structures. Second, we describe an idea of interconnection of Dirac structures; namely, we show how two distinct Lagrange-Dirac systems can be interconnected through a Dirac structure on the product of configuration spaces. Third, we also show the variational structure of the interconnected Lagrange-Dirac dynamical system in the context of the Hamilton-Pontryagin-d'Alembert principle. Finally, we demonstrate our theory by an example of mass-spring mechanical systems.**

## Interpolation and Approximation in Linear Systems – 1
*(Invited Session)*

**Room 12**

***Organizers:*** *Andrea Gombani, Martine Olivi*
***Chair:*** *Andrea Gombani*

10.30 – 11.00

Minimal Symmetric Darlington Synthesis: the Real Case
*Laurent Baratchart, Per Enqvist, Andrea Gombani, Martine Olivi*

***Abstract*–We consider the symmetric Darlington synthesis of a $p \times p$ rational symmetric Schur function S with the constraint that the extension is of size $2p \times 2p$ and**

we investigate what happens when we impose that *S* and its extension have real coefficients. In this case, under the assumption that *S* is strictly contractive in at least one point of the imaginary axis, we determine the an upper bound for the McMillan degree of the extension. A constructive characterization of all such extensions is provided in terms of a symmetric realization of *S* and of the outer spectral factor of $I_p - SS^*$.

11.00 – 11.30

Convergent Rational Interpolation to Cauchy Integrals on an Arc
*Laurent Baratchart, Maxim Yattselev*

*Abstract*–We design convergent rational interpolation schemes to functions defined as Cauchy integrals of complex densities over open analytic arcs, under mild smoothness assumptions on the density. The interpolation points must be chosen according to the geometry of the arc, and the convergence is locally uniform outside of the arc. The result essentially settles the convergence issue of multipoint Padé approximants to functions with connected singular set of dimension 1.

11.30 – 12.00

Approximative Covariance Interpolation
*Per Enqvist*

*Abstract*–When methods of moments are used for identification of power spectral densities, a model is matched to estimated second order statistics such as, e.g., covariance estimates. If the estimates are good there is an infinite family of power spectra consistent with such an estimate and in applications, such as identification, we want to single out the most representative spectrum. We choose a prior spectral density to represent a priori information, and the spectrum closest to it in a given quasi-distance is determined. However, if the estimates are based on few data, or the model class considered is not consistent with the process considered, it may be necessary to use an approximative covariance interpolation. Two different types of regularizations are considered in this paper that can be applied on many covariance interpolation based estimation methods.

12.00 – 12.30

LMI Conditions of Strictly Bounded Realness on a State-Space Realization to Bi-Tangential Rational Interpolation
*Yohei Kuroiwa*

*Abstract*–We present LMI conditions to characterize the strictly bounded realness of the state-space realization of the solution to the bi-tangential rational interpolation problem with McMillan degree constraint.

## Linear Stochastic Systems, the White Noise Space, and Related Topics
*(Invited Session)*

**Room 13**

***Organizer:*** *Daniel Alpay*
***Chair:*** *Daniel Alpay*

10.30 – 11.00

An Introduction to White Noise Theory and Linear Stochastic Systems
*Daniel Alpay, David Levanony*

*Abstract*–In a recent paper which appeared in Acta Applicandae Mathematicae, the authors developed a new approach to linear stochastic systems and proved a number of stability theorems for linear time invariant stochastic systems. In this approach, one works in the white noise space (or in the Kondratiev space, which is an inductive limit of Hilbert spaces which contains it) and replaces the usual product by the Wick product. Most, if not all, of classical system theory extends to this setting. In the talk we review this setting, and present some new results on stochastic linear systems.

11.00 – 11.30

Discrete Multiscale Systems: Stability Results
*Daniel Alpay, Mamadou Mboup*

*Abstract*–We introduce discrete time-scale filtering by the way of certain double convolution systems. We prove stability theorems for these systems and make connections with function theory in the poly-disc.We also make connections with the white noise space framework.

11.30 – 12.00

Stochastic integration for a Class of Gaussian Processes
*Daniel Alpay, Haim Attia, David Levanony*

*Abstract*— Using the Gelfand triple which consists of the space of Kondratiev test functions, of the white noise space and of the Kondratiev space of stochastic distributions we build models for processes with covariance functions of the form

$$K_r(t,s) = r(t) + r(s)^* - r(t-s) - r(0), \quad t,s \in \mathbb{R},$$

and their derivatives . We study stochastic integration for a class of processes which include the fractional Brownian motion. We also present an Ito-type formula in this setting. The theory of countably normed spaces and of their duals play a key role in the arguments.

12.00 – 12.30

On a Schur Class of Functions whose Values are Operators between Banach Spaces
*Dan Volok*

*Abstract*–In this talk we shall introduce a Schur class of functions whose values are operators between Banach spaces and present a characterization of the related de Branges - Rovnyak spaces. This is a joint work with D. Alpay, O. Timoshenko and P. Vegulla.

## LDPC and Applications
*(Invited Session)*

**Room 14**

***Organizers:*** *Joachim Rosenthal, Marcus Greferath*
***Chair:*** *Joachim Rosenthal*

10.30 – 11.00

Exploration of AWGNC and BSC Pseudocodeword Redundancy
*Jens Zumbrägel, Mark F. Flanagan, Vitaly Skachek*

*Abstract*— The AWGNC, BSC, and max-fractional *pseudocodeword redundancy* $\rho(\mathcal{C})$ of a code $\mathcal{C}$ is defined as the smallest number of rows in a parity-check matrix such that the corresponding minimum pseudoweight is equal to the minimum Hamming distance of $\mathcal{C}$. This paper provides new results on the AWGNC, BSC, and max-fractional pseudocodeword redundancies of codes. The pseudocodeword redundancies for all codes of small length (at most 9) are computed. Also, comprehensive results are provided on the cases of cyclic codes of length at most 250 for which the eigenvalue bound of Vontobel and Koetter is sharp.

11.00 – 11.30

Cross-Correlation of Costas Arrays: the Current Status
*Konstantinos Drakakis, Scott Rickard*

**_Abstract_–We study the cross-correlation of pairs of Costas arrays, and more specifically its maximal value over the families of Golomb and Welch permutations. We record the numerical results found, analyze them, formulate conjectures summarizing our findings, and present the current progress towards a rigorous proof of these conjectures.**

11.30 – 12.00

LDPC Codes from Matrix Equations
*Ariel Amir, Abigail Mitchell, Joachim Rosenthal*

**_Abstract_–Different constructions of LDPC codes based on matrix equations are investigated. The parameters such as the dimension, rate and distance are computed. The classical Tanner graph representation known for LDPC codes are described. The main difference between standard LDPC codes and the LDPC codes based on matrix equations lies in the structure of their codewords. Whereas in the classical situation codewords are simply vectors, the codewords in this new setting will be two-dimensional vectors or matrices. This implies that the parity-check constraints must be satisfied in both perpendicular directions of the codeword. Therefore, a codeword may be interpreted as a two-dimensional array which is suitable for recording on two-dimensional pattern-oriented storage media.**

12.00 – 12.30

On Binary Self-Dual Extremal Codes
*Wolfgang Willems*

**_Abstract_–There is a large gap between Zhang's theoretical bound for the length n of a binary extremal self-dual doublyeven code and what we can construct. The largest n is 136. In order to find examples for larger n a non-trivial automorphism group might be helpful. In the list of known examples extended quadratic residue codes and quadratic double circulant codes have large automorphism groups. But in both classes the extremal ones are all known. They are exactly those which are in the list; hence of small length. The investigations we have done so far give some evidence that for larger n the automorphism group of a putative extremal self-dual doubly-even code may be very small, if not trivial. Thus the code merely seems to be a big combinatorial object and therefore possibly hard to find.**

## 2D Systems
*(Invited Session)*

**Room 15**

***Organizers:*** *Marek Majewski, Dariusz Idczak*
***Chair:*** *Marek Majewski*

10.30 – 11.00

Positive Switched 2D Linear Systems Described by the Roesser Models
*Tadeusz Kaczorek*

**_Abstract_–In this paper the positive switched 2D linear system described by the Roesser models will be considered. We shall analyzed the following question: When is a positive switched 2D linear system defined by a linear Roesser models and a rule describing the switching between them asymptotically stable. It is well known [1, 3] that a necessary and sufficient conditions for stability under arbitrary switching is the existence of a common Lyapunov function for the family of subsystems. This result will be extended for positive switched 2D linear systems described by the Roesser models.**

11.00 – 11.30

A New Approach to Strong Practical Stability and Stabilization of Discrete Linear Repetitive Processes
*Pawel Dabkowski, Krzysztof Gałkowski, Olivier Bachelier, Eric Rogers, James Lam*

**_Abstract_–Repetitive processes are a distinct class of 2D systems of both theoretical and practical interest. The stability theory for these processes originally consisted of two distinct concepts termed asymptotic stability and stability along the pass respectively where the former is a necessary condition for the latter. Recently applications have arisen where asymptotic stability is too weak and stability along the pass is too strong for meaningful progress to be made. This, in turn, has led to the concept of strong practical stability for such cases, where previous work has formulated this property and obtained necessary and sufficient conditions for its existence together with Linear Matrix Inequality (LMI) based tests, which then extend to allow control law design. This paper develops considerably simpler, and hence computationally more efficient, stability tests that also extend to allow control law design.**

11.30 – 12.00

2D Systems with Controls and Some their Applications
*Dorota Bors, Stanisław Walczak*

**_Abstract_–We consider the 2D continuous counterpart of Marchesini-Fornasini model of the process of gas filtration. The continuous version of the discrete model constitutes the hyperbolic boundary value problem. Our main result is finding sufficient conditions for the existence of an optimal solution for the process of gas filtration minimizing the cost functional.**

12.00 – 12.30

Fractional Differential Repetitive Processes
*Dariusz Idczak, Rafał Kamocki*

In the paper, we consider the following fractional differential repetitive process

$$\begin{cases} (D^{\alpha}_{a+}z_{k+1})(t) = A_1 z_{k+1}(t) + A_2 w_k(t) + B u_{k+1}(t) \\ w_{k+1}(t) = C_1 z_{k+1}(t) + C_2 w_k(t) + D u_{k+1}(t) \end{cases}$$

for $k \in \mathbb{N} \cup \{0\}$, $t \in \mathbb{R}$, $0 \le t \le \beta$, with initial conditions

$$\begin{cases} (I^{1-\alpha}_{a+} z_k)(0) = 0 \text{ for } k \in \mathbb{N}, \\ w_0(t) = 0 \text{ for } t \in \mathbb{R},\ 0 \le t \le \beta, \end{cases}$$

Here $D^{\alpha}_{a+}z_k$, $I^{1-\alpha}_{a+}z_k$ are derivative of order $\alpha \in (0,1)$ and integral of order $1-\alpha$ of the function $z_k$, in the Riemann-Liouville sense.

Classical differential repetitive processes (with $\alpha = 1$) are extensively studied for over twenty years. They have numerous applications - in modeling of long-wall coal cutting, metal rolling and chemical batch processes, in programming of robotic manipulators. Recent investigations show that the dynamics of many systems are described more accurately with the aid of fractional derivatives. The above model can be used in the study of linear repetitive processes connected with such systems.

We derive existence, uniqueness and continuous dependence of solutions $z_k$ on controls $u_k$.

## Semiplenary Lecture

**Room 1**

***Chair:*** *Floyd B. Hanson*

14.00 – 15.00

Modelling High Dimensional Time Series by Generalized Factor Models
*Manfred Deistler*
*(joint work with B.D.O. Anderson, A. Filler, W. Chen)*

***Abstract*–We discuss and analyze generalized linear dynamic factor models. These models have been developed recently and they are used to model high dimensional time series in order to overcome the "curse of dimensionality". The basic idea in factor models is to seperate "comovement" between the variables (caused by a relatively small number of factors) from individual (idiosyncratic) variation. Here factor analysis is considered in a time series context, where concentration of information is performed in the cross-sectional and in the time dimension. The models considered are linear dynamic in nature and stationarity of the processes is assumed. As opposed to the classical case, in the generalized case considered here, a certain form of weak dependence of the noise components is permitted. In the core part of the paper, we are concerned with structure theory, namely with realizing the singular rational spectral density of the latent variables by a linear system. Special emphasis ! is laid on the autoregressive case, which is generic in our setting. These autoregressions may have a singular innovation variance, which may cause multiple solutions for the Yule Walker equations. Finally, identification procedures, using a suitable denoising procedure and estimators suggested by our structure theory, are discussed.**

## Semiplenary Lecture

**Room 14**

***Chair:*** *Yutaka Yamamoto*

14.00 – 15.00

Smith-Predictor Type Structure for a Class of Infinite-Dimensional Systems: Optimal Control and Performance Limitation Formula
*Kenji Kashima*

***Abstract*–In this talk we investigate control problems for infinite-dimensional systems whose transfer matrices are expressible in terms of a rational transfer matrix and a scalar (possibly irrational) inner function. This class of systems is capable of describing many practical control problems, when weighting functions are rational and plants have at most a finite number of unstable modes or zeros. In the first half of this talk the concept of Smith-predictors, that was originally used for I/O delay systems, is extended to the aforementioned class of systems. This allows us to reduce the optimal control problems to easily checkable criteria that do not require the solution of operator-valued equations. Furthermore, the obtained (stabilizing or suboptimal) controllers are shown to have the structure of Smith-predictors, or their dual. In the second half of the talk we derive a new expression for the $H^2$ performance limit, based on state-space representation. The resulting formula, given as a functional of the inner function, helps us to understand how achievable $H^2$ performance deteriorates due to the plant's nonminimum phase properties or unstable modes. The example of a linear quantum control system suffering from feedback delay is given to illustrate the result.**

## Semiplenary Lecture

**Room 15**

***Chair:*** *Peter E. Caines*

14.00 – 15.00

Some Problems with Connecting Renewable Energy Sources to the Grid
*George Weiss, Qing-Chang Zhong*

***Abstract*–In this paper, we review some challenges resulting from the grid connection of powerful renewable energy generators that produce randomly fluctuating power and have no mechanical inertia. We propose and develop the idea of operating an inverter to mimic a synchronous generator. We call the inverters that are operated in this way synchronverters. Using synchronverters, the well-established theory/algorithms used to control synchronous generators can still be used in power systems where a significant proportion of the generating capacity is inverter-based. We describe the dynamics, implementation and operation of synchronverters. The real and reactive power delivered by synchronverters connected in parallel and operated as generators can be automatically shared using the well-known frequency and voltage drooping mechanisms. Synchronverters can be easily operated also in island mode and hence they provide an ideal solution for microgrids or smart grids.**

## Continuous-Time Model Identification
*(Invited Session)*

**Room 1**

***Organizer:*** *Toshiharu Sugie*
***Chair:*** *Toshiharu Sugie*

15.30 – 16.00

Continuous-Time Model Identification and State Estimation Using Non-Uniformly Sampled Data
*Rolf Johansson*

***Abstract*–This contribution reviews theory, algorithms, and validation results for system identification of continuous-time state-space models from finite inputoutput sequences. The algorithms developed are autoregressive methods, methods of subspace-based model identification and stochastic realization adapted to the continuous-time context. The resulting model can be decomposed into an input-output model and a stochastic innovations model. Using the Riccati equation, we have designed a procedure to provide a reduced-order stochastic model that is minimal with respect to system order as well as the number of stochastic inputs, thereby avoiding several problems appearing in standard application of stochastic realization to the model validation problem. Next, theory, algorithms and validation results are presented for system identification of continuous-time state-space models from finite non-uniformly sampled input-output sequences. The algorithms developed are methods of model identification and stochastic realization adapted to the continuous-time model context using non-uniformly sampled input-output data. The resulting model can be decomposed into an input-output model and a stochastic innovations model. For state estimation dynamics and Kalman filters, we have designed a procedure to provide separate continuous-time temporal update and error feedback update based on non-uniformly sampled input-output data.**

16.00 – 16.30

Frequency Domain Total Least Squares Estimator of Time-Varying Systems

*John Lataire, Rik Pintelon*

***Abstract*–An identification procedure for linear continuoustime, time-varying systems is presented. The model considered is an ordinary differential equation whose coefficients are polynomials in time. The model equation is evaluated in the frequency domain (thus allowing a simple selection of the frequency band of interest) from sampled, finite length records of the input and output signals. The time-frequency transformations are performed using the Discrete Fourier Transform and its inverse. The leakage and alias errors (due to the nonperiodicity of the system's response) are shown to be easily captured by adding a polynomial to the model equation. The identification procedure is formulated as a total least squares estimation problem. The estimator is illustrated on a simulation example.**

16.30 – 17.00

EM Identification of Continuous–Time State Space Models from Fast Sampled Data

*Juan I. Yuz, Jared Alfaro, Juan C. Agüero, Graham C. Goodwin*

***Abstract*–In this paper we apply the Expectation-Maximization (EM) algorithm to the identification of continuous-time state-space models from fast sampled data. We modify the standard EM formulation, using a parametrization of the sampled-data model in incremental form. This model recovers the underlying continuous-time system when the sampling period goes to zero. Also, the use of the incremental model parametrization shows better numerical behavior for fast sampling rates. We also consider the case of non–uniform sampling and a robust identification procedure that can be applied in the time or frequency domain.**

## Filtering, Estimation and Control

*(Regular Session)*

**Room 2**

***Chair:*** *Lorenzo Finesso*

15.30 – 16.00

Two-Step Nonnegative Matrix Factorization Algorithm for the Approximate Realization of Hidden Markov Models

*Lorenzo Finesso, Angela Grassi, Peter Spreij*

***Abstract*–We propose a two-step algorithm for the construction of a Hidden Markov Model (HMM) of assigned size, i.e. cardinality of the state space of the underlying Markov chain, whose n-dimensional distribution is closest in divergence to a given distribution. The algorithm is based on the factorization of a pseudo Hankel matrix, defined in terms of the given distribution, into the product of a tall and a wide nonnegative matrix. The implementation is based on the nonnegative matrix factorization (NMF) algorithm. To evaluate the performance of our algorithm we produced some numerical simulations in the context of HMM order reduction.**

16.00 – 16.30

Recursive Identification of Continuous-Time Linear Stochastic Systems - An Off-Line Approximation

*László Gerencsér, Vilmos Prokaj*

***Abstract*–We consider multi-variable continuous-time linear stochastic systems given in innovation form, with system matrices depending on an unknown parameter that is locally identifiable. A computable continuous-time recursive maximum likelihood (RML) method with resetting has been proposed in our ECC 09 paper. Resetting takes place if the estimator process hits the boundary of a pre-specified compact domain, or if the rate of change, in a stochastic sense, of the parameter process would hit a fixed threshold. An outline of a proof of convergence almost surely and in $L_q$ was given, under realistic conditions. In the present paper we show that the RML estimator differs from the off-line estimator by an error of the magnitude of log*T/T* in an appropriate sense. With this result a conjecture formulated back in 1984 has been settled.**

16.30 – 17.00

Mean-Square Minimization in Mathematical Finance with Control and State Constraints

*Andrew J. Heunis*

***Abstract*–We study a problem of optimal stochastic control from mathematical finance. The problem involves both a control constraint (on the portfolio) together with an almostsure state constraint (on the wealth process), giving a rather challenging combination of constraints. We demonstrate existence of a Lagrange multiplier, show that this is a pair comprising a finitely additive measure (for the state constraint) and an Ito process (for the portfolio constraint), and construct an optimal portfolio in terms of the Lagrange multiplier.**

17.00 – 17.30

Convergence of the MAP Path Estimator in HMMs with Continuous Hidden State Space

*Pavel Chigansky, Ya'acov Ritov*

***Abstract*— Consider the conventional hidden Markov model $(X,Y)=(X_n,Y_n)_{n\geq 1}$, where the signal process $X$ is a Markov sequence and the observation process $Y$ is a sequence of conditionally independent random variables, given $X$, where the conditional distribution of $Y_n$ depends only on $X_n$ at any time $n\geq 1$.**

**One of the basic problems in this setup is to estimate the signal trajectory $X_{1:n}$, given an observed trajectory $Y_{1:n}$. The MAP estimator is a solution of the optimization problem**

$$\hat{X}^n_{1:n}=\mathrm{argmax}_{x_{1:n}} r(x_1)\prod_{m=2}^{n} q(x_{m-1},x_m)p(x_m,Y_m),$$

**where $r(\cdot)$ and $q(\cdot,\cdot)$ are initial and transition probability densities of $X$ respectively, and $p(\cdot,\cdot)$ is the emission density, from which $Y_n$'s are sampled. The superscript $n$ in $\hat{X}^n_{1:n}$ emphasizes the dependence of the optimal trajectory on the time horizon of the problem.**

**We shall address the existence of the limit $\lim_{n\to\infty}\hat{X}^n_{1:m}$ for any fixed $m$. In practical terms, such a limit means that the optimal path ceases to depend on the future data and the optimization algorithm can be localized. We shall see that such convergence cannot be taken for granted and that the optimal path may stabilize in a way, essentially different from the previously considered finite state setting.**

## PDE Systems

*(Regular Session)*

**Room 3**

***Chair:*** *Joao R. Branco*

15.30 – 16.00

Integro-Differential IBVP versus Differential IBVP: Stability Analysis

*Joao R. Branco, José Augusto Ferreira*

***Abstract*–The aim of this work is the qualitative analysis from theoretical and numerical points of view of an integro-differential initial boundary value problem where the reaction term presents a certain memory efect. Stability results are established in both cases. As in certain cases the integro-differential initial boundary value problem can be seen as a**

**differential initial boundary value problem, the results obtained for the integro-differential formulation are compared with the correspondent results stated for the diferential initial boundary value problem. Numerical results illustraing the theoretical results are also presented.**

16.00 – 16.30

Distributed Source Identification for Wave Equations: an Observer-Based Approach

*Marianne Chapouly, Mazyar Mirrahimi*

***Abstract*–In this paper, we consider a wave equation on a bounded interval where the initial conditions are known (are zero) and we are rather interested in identifying an unknown source term *q(x)* thanks to the measurement output *y* which is the Neumann derivative on one of the boundaries. We use a back and forth iterative procedure and construct well-chosen observers which allow to retrieve *q* from *y* in the minimal observation time.**

16.30 – 17.00

Block Preconditioned Methods in Solution of Hyperbolic Equations

*Ahmad Shayganmanesh (Golbabai), M.M. Arabshahi*

***Abstract*— In this article, we compare suitable preconditioners for solving linear systems arising from the class of fourth-order approximations employed for solving hyperbolic equations, $\alpha u_{tt} + \beta u_{xx} = f(x,t,u,u_x,u_t)$ subject to appropriate initial and boundary conditions, where $\alpha$ and $\beta$ are constants. Numerical results show that the proposed preconditioned methods produces an accurate and oscillation free solution.**

17.00 – 17.30

The Best State Space for the SCOLE Model

*Xiaowei Zhao, George Weiss*

***Abstract*–It is well-known that the SCOLE model (a beam coupled to a rigid body) is not exactly controllable in the energy state space with $L^2$ input signals, since the control operator is compact from the input space to state space. In this paper, we derive its exactly controllable space for $L^2$ input signals and we prove its well-posedness and regularity in this space.**

## Algebraic Systems Theory, Behaviors, and Codes: New Developments Beyond Classical Algebraic Coding Theory

*(Invited Session)*

**Room 4**

***Organizers:*** *Heide Glüsing-Lürssen, Eva Zerz*
***Chair:*** *Heide Glüsing-Lürssen*

15.30 – 16.00

New Improvements on the Echelon-Ferrers Construction

*Anna-Lena Trautmann, Joachim Rosenthal*

***Abstract*–We show how to improve the echelon-Ferrers construction of random network codes introduced in [3] to attain codes of larger size for a given minimum distance.**

16.00 – 16.30

On the Weight Hierarchy of Certain Grassmann Codes

*Arunkumar R. Patil, Harish K. Pillai*

***Abstract*— The higher weights $d_r$ and $d_{k-r}$ of the $[n,k]_q$-(linear) Grassmann code $C(\ell,m)$ associated with a Grassmannian $G(\ell,m)$ over the finite field $\mathbb{F}_q$ are known for $0 \le r \le \mu$ where $\mu = \max\{\ell, \mathrm{m}-\ell\}+1$. Grassmann codes are generalizations of Reed-Muller codes. These codes are constructed using Grassmann varieties $G(\ell,m)$ (all $\ell$ dimensional subspaces of a $m$-dimensional space $\mathbb{F}_q^m$ over the finite field $\mathbb{F}_q$). The $r$-th higher weight of a code is defined as the minimum weight of any $r$-dimensional sub-code of the given code. The collection of all the higher weights, $1 \le r \le k$, where $k$ is the dimension of the code, is called the weight hierarchy of the code. For Grassmann codes, only a very small portion of this weight hierarchy is known. In this paper, we demonstrate a method of determining the complete weight hierarchy of some special Grassmann codes, namely those coming from $G(2,m)$.**

***Index Terms*— Grassmann codes, projective system, higher weights, completely decomposable vectors,Young tableaux.**

16.30 – 17.00

The Shortest-Basis Approach to Minimal Realizations of Linear Systems

*G. David Forney Jr.*

***Abstract*— Given a controllable discrete-time linear system $\mathcal{C}$, a shortest basis for $\mathcal{C}$ is a set of linearly independent generators for $\mathcal{C}$ with the least possible lengths. A basis $\mathcal{B}$ is a shortest basis if and only if it has the predictable span property (*i.e.*, has the predictable delay and degree properties, and is non-catastrophic), or alternatively if and only if it has the subsystem basis property (for any interval $\mathcal{J}$, the generators in $\mathcal{B}$ whose span is in $\mathcal{J}$ is a basis for the subsystem $\mathcal{C}_{\mathcal{J}}$). The dimensions of the minimal state spaces and minimal transition spaces of $\mathcal{C}$ are simply the numbers of generators in a shortest basis $\mathcal{B}$ that are active at any given state or symbol time, respectively. A minimal linear realization for $\mathcal{C}$ in controller canonical form follows directly from a shortest basis for $\mathcal{C}$, and a minimal linear realization for $\mathcal{C}$ in observer canonical form follows directly from a shortest basis for the orthogonal system $\mathcal{C}^{\perp}$. This approach seems conceptually simpler than that of classical minimal realization theory.**

17.00 – 17.30

Correlations in Stream Ciphers: a Systems Theory Point of View

*Sara Diaz Cardell, Gerard Maze, Joachim Rosenthal, Urs Wagner*

***Abstract*–Given a sequence of some autonomous behavior, this sequence can be computed as the output of a linear system. If one receives a highly noisy sequence correlated with such a linear sequence, the problem we study is how to obtain the input of the linear system. We explain known correlation attacks in this general setting and we show types of autonomous behaviors which should be avoided.**

## Systems Theory and the Economics of Pricing in New Markets

*(Invited Session)*

**Room 6**

***Organizers:*** *Robert Martin, Clyde F. Martin*
***Chair:*** *Robert Martin*

15.30 – 16.00

Systems and Markets: Instability and Irrationality

*Robert Martin, Clyde F. Martin, Xuyao Lin*

***Abstract*–New financial products are difficult to price. Often the products suffer through an initial period of price**

volatility as the market searchers for an equilibrium value. In this paper, we extend our previous results by showing that the rate of convergence is extremely slow, less than sqrt(N), where N is the number of draws. As a result with a sufficiently low discount rate, an investor gambling on draws from the urn faces possibility of time-relevant unbounded losses. Why do these losses fail to prevent the market from forming? Are investors then inherently irrational? Because the market price is an average of the beliefs of many investors rather than a reflection of the truth. Therefore, any investor who believes their priors better than the market's also believes they have unbounded earning potential. As a result, the market thrives, volatility persists, and some investors win at the expense of others.

16.00 – 16.30

A General Theory of Markovian Time Inconsistent Stochastic Control Problems
*Tomas Björk, Agatha Murgoci*

***Abstract*–We develop a theory for stochastic control problems which, in various ways, are time inconsistent in the sense that they do not admit a Bellman optimality principle. We attach these problems by viewing them within a game theoretic framework, and we look for Nash subgame perfect equilibrium points. For a general controlled Markov process and a fairly general objective functional we derive an extension of the standard Hamilton-Jacobi-Bellman equation, in the form of a system of non-linear equations, for the determination for the equilibrium strategy as well as the equilibrium value function. All known examples of time inconsistency in the literature are easily seen to be special cases of the present theory. We also prove that for every time inconsistent problem, there exists an associated time consistent problem such that the optimal control and the optimal value function for the consistent problem coincides with the equilibrium control and value function respectively for the time inconsistent problem. We also study some concrete examples.**

16.30 – 17.00

A Model for Multiscaling and Clustering of Volatility in Financial Indexes
*Alessandro Andreoli, Francesco Caravenna, Paolo Dai Pra, Gustavo Posta*

***Abstract*–We propose a stochastic model which matches some relevant stylized facts observed in time series of financial indexes, and that are not fully captured by the models most often used in this context. These stylized facts concern with the distribution of the log-returns (increments of the logarithm of the index). This distribution is not Gaussian, and its moments obey peculiar scaling relations (multiscaling). Moreover, absolute values of log-returns in disjoint time intervals are positively correlated (clustering of volatility): their correlation has slow (sub-exponential) decay for moderate time distances (up to few months), and have a faster decay for larger distances. The simplicity of the model allows sharp analytic results, statistical estimation of its few parameters, and low computational effort in simulations, allowing its concrete use in applications such as option pricing.**

17.00 – 17.30

Arbitrage-Free Multifactor Term Structure Models: a Theory Based on Stochastic Control
*Andrea Gombani, Wolfgang J. Runggaldier*

***Abstract*–We present an alternative approach to the pricing of bonds and bond derivatives in a multivariate linear-quadratic model for the term structure that is based on the solution of a linear-quadratic stochastic control problem. We focus on explicit formulas for the computation of bond options in a bivariate factor model which can be easily computed numerically by calculating four line integrals.**

## Biological Networks
*(Regular Session)*

**Room 7**

***Chair:*** *Siamak Taati*

15.30 – 16.00

Gene Regulatory Networks: the Impact of Distance between Genes
*Gilles Bernot, Jean-Paul Comet, Enrico Formenti, Siamak Taati*

***Abstract*–We analyze the basic building block of gene regulation networks using a simple stochastic model. We consider a network consisting only of two interacting genes: an activator (or repressor) gene that produces proteins of type S and a target gene that is activated (or repressed, respectively) by proteins of type S. We identify the role of distance between the two interacting genes by calculating the relative density of those activator proteins that until time t have succeeded in reaching the vicinity of the target gene via an unbiased threedimensional Brownian motion. The latter quantity seen as a function of time has a sigmoidal shape (like a simple delay line) that is sharper and taller when the two genes are closer to each other. This suggests an evolutionary pressure towards making the interacting genes closer to each other to make their interactions more efficient and more reliable.**

16.00 – 16.30

Controlling Gene Regulatory Networks by Means of Control Systems Theory Principles and Microfluidic Devices
*Filippo Menolascina, Mario di Bernardo, Diego di Bernardo*

16.30 – 17.00

Estimation of Protein Networks for Cell Cycle in Yeast Based on Least–Squares Method Using Periodic Signals
*Noriko Takahashi, Takehito Azuma, Shuichi Adachi*

***Abstract*–In this paper, a new approach to estimation problems of protein networks is proposed for systems biology. Generally, it is difficult to estimate complicated networks in molecular biology. Then, in order to estimate complicated networks systematically, it is considered to estimate the networks based on a control engineering method. Considering that wave patterns of proteins are periodic, the protein networks are estimated by the least–squares estimation method. In this method, the networks can be estimated by using just 1 cycle data of protein concentrations. Moreover, this method is applied to an estimation problem of protein networks for cell cycle in yeast, and 9–dimensional protein networks are actually estimated.**

## Signal Processing
*(Regular Session)*

**Room 8**

***Chair:*** *Kenadall Gillies*

15.30 – 16.00

Convergence of Bayesian Posterior Distributions
*Kenadall Gillies, Robert Martin, Shan Sun, Clyde F. Martin*

***Abstract*–This paper will compare the model of determining the true price of a product to determining the proportion of black balls in a bottomless, rotating urn. In doing this it is seen that as long as the ratio of black balls converge to the true proportion, the Bayesian updating method for the $r^{th}$ moment will converge to the true proportion raised to the $r^{th}$ power.**

**Thus the posterior distributions converge to unit mass at the true proportion. A theory for speeding up the convergence rate for the Bayesian updating method was then tested since it now known that the Bayesian updating method converges.**

16.00 – 16.30

High Resolution Analysis via Sparsity-Inducing Techniques: Spectral Lines in Colored Noise

*Lipeng Ning, Tryphon T. Georgiou, Allen R. Tannenbaum*

***Abstract*–The impact of sparsity-inducing techniques in signal analysis has been recognized for over ten years now and has been the key to a growing literature on the subject– commonly referred to as compressive sensing. The purpose of the present work is to explore such sparsity-inducing techniques in the context of system identification. More specifically we consider the problem of separating sinusoids in colored noise while at the same time identifying the dynamics that generate the wide-bandwidth noise-component. Our formalism relies on modeling the data as a superposition of a few unknown sinusoidal signals together with the output of an auto-regressive filter which is driven by white noise. Naturally, since neither the underlying dynamics nor any possible sinusoids present are known, the problem is ill-posed. We seek a sparse selection of sinusoids which together with the auto-regressive component can account for the data-set and, to this end, we propose a suitable modification of sparsity-inducing functionals (a la LASSO/Basis pursuit/etc.) which can generate admissible solutions-their sparsity being determined by tuning parameters.**

16.30 – 17.00

Probabilistic Current-State Opacity is Undecidable

*Anooshiravan Saboori, Christoforos N. Hadjicostis*

***Abstract*–Increasing concerns about security and privacy in applications of discrete event systems have led to various notions of opacity for systems that are modeled as (possibly non-deterministic) finite automata with partial observation on their transitions. Specifically, a system is current-state opaque if the entrance of the system state to a given set of secret states remains opaque (uncertain), until the system leaves this set of secret states, to an intruder who observes system activity through some projection map. While this notion has been shown useful for security requirements in many applications (including encryption using pseudo-random generators and coverage properties in sensor networks), it does not provide a quantifiable measure for characterizing the security of a given system. In this paper, we extend this framework to systems that can be modeled as probabilistic finite automata, obtaining in the process the probability of observing sequences of observations that violate current-state opacity. We then introduce and analyze the notion of probabilistic current-state opacity which can be used to provide a measure of a given system's opacity. We show that verifying probabilistic currentstate opacity is undecidable in general, though it can become decidable in specific settings.**

## Switched Systems

*(Regular Session)*

**Room 9**

***Chair:*** *Koichi Kobayashi*

15.30 – 16.00

Free-Variable Analysis of Finite Automata Representations for Hybrid Systems Control

*Koichi Kobayashi, Jun-ichi Imura*

***Abstract*–As is well known, the computational complexity in the mixed integer programming (MIP) problem is one of the main issues in model predictive control of hybrid systems such as mixed logical dynamical systems. To overcome this issue, the authors have proposed a new method to represent a deterministic finite automaton as a linear state equation with a relatively smaller number of (free) binary input variables, which thus makes the number of binary variables in the resultant MIP problem smaller. This paper continues upon the above approach, and presents theoretical aspects on input binary variables in the linear state equation model such as the upper bound of the number of the binary input variables.**

16.00 – 16.30

Disturbance Decoupling Problems with Quadratic Stability for Switched Linear Systems via State Feedback

*Naohisa Otsuka*

***Abstract*–In this paper disturbance decoupling problems without stability and with quadratic stability for switched linear systems are formulated in the framework of the so-called geometric approach. Firstly, necessary and sufficient conditions for the problem without stability to be solvable are given. Secondly, sufficient conditions for the problem with quadratic stability to be solvable are given. Further, for switched linear systems composed of two subsystems necessary and sufficient conditions for the problem with quadratic stability to be solvable are also investigated. Finally, an illustrative example is shown.**

16.30 – 17.00

Output Feedback Stabilizing Control and Passification of Switching Diffusion Systems

*Pavel V. Pakshin, Dimitri Peaucelle*

***Abstract*–A parametric description of static output feedback stabililizing controllers for diffusion systems with Markovian switching is presented. This description is expressed in terms of coupled linear matrix equations and non-convex quadratic matrix inequalities which depend on parameter matrices similar to weight matrices in LQR theory. A convexifying approximation technique is proposed to obtain the LMI-based algorithms for computing of the gain matrix. These are non-iterative and used computationally efficient SDP solvers.The results are then applied to simultaneous stabilization of a set of diffusion systems, robust stabilization and stochastic passification problems. Finally, a numerical example is provided to demonstrate the applicability and effectiveness of the proposed method.**

17.00 – 17.30

On Well-Posedness of Piecewise Affine Bimodal Dynamical Systems

*Le Q. Thuan, Kanat Camlibel*

***Abstract*–The theory of differential inclusions provides certain sufficient conditons for the uniqueness of Filippov solutions such as one-sided Lipschitzian property or maximal monotone condition. When applied to piecewise affine dynamical systems, these conditions impose rather strong conditions. In this paper, we provide less restrictive conditions for uniqueness of Filippov solutions for the bimodal piecewise affine systems.**

## Advanced Linear Algebra – 2
*(Regular Session)*

**Room 10**

***Chair:*** *Christophe Fonte*

15.30 – 16.00

Conditions for Interpolation of Stable Polynomials
*Christophe Fonte, Cédric Delattre*

***Abstract***–**This contribution addresses the problem of the interpolation of a set of positive numbers by stable real polynomials. It is shown that the interpolant preserves local positivity, monotonicity, and convexity in order to satisfy stability requirement of the interpolating polynomial. Then this issue is formulated as a nonlinear system carrying on the existence of negative real roots and positive real parameters. By considering an extension of the Farkas's Lemma and the method of Fourier- Motzkin elimination, conditions are explicitly produced for the existence of an Hurwitz polynomial that passes through all the pairs of values to interpolate.**

16.00 – 16.30

Convexity of Higher Dimensional Numerical Ranges
*Michael Karow*

***Abstract***— **The talk deals with the convexity of the joint numerical range $W(A)$ of an $m$-tuple of Hermitian matrices $A = (A_1, \dots, A_m)$, $A_k \in \mathbb{C}^{n\times n}$, $A_k^* = A_k$. By definition,**

$$W(A) = \{\, (x^* A_1 x, \dots, x^* A_m x)^\top;\ \ x \in \mathbb{C}^n,\ \|x\|_2 = 1\} \subset \mathbb{R}^m.$$

**Joint numerical ranges and their convexity play an important role in the theory of $\mu$-values (structured singular values) with respect to blockdiagonal perturbations and the spectral norm [2,3,4,5,6]. It is well known that $W(A)$ is convex if $m = 2$ and if $m = 3$ and $n > 2$. We give the following criterion for the convexity of $W(A)$ if $m \geq 4$. Suppose the largest eigenvalue of $A(\eta) = \sum_{k=1}^{m} \eta_k A_k$, has constant multiplicity for all $0 \neq \eta \in \mathbb{R}^m$. Then either $W(A)$ is a smooth convex body or $W(A)$ is a smooth convex surface. Furthermore, if $W(A)$ is convex though the eigenvalue condition fails then the convexity can be destroyed by an arbitrarily small perturbation of $A$. The results are obtained using methods from differential topology.**

**The talk is based on joint work with E. Gutkin and E. Jonckheere [1].**

16.30 – 17.00

Real Radius of Controllability for the Systems Described by Polynomial Matrices: SIMO Case
*Swanand R. Khare, Harish K. Pillai, Madhu N. Belur*

***Abstract***–**In this paper we discuss the problem of computing the real radius of controllability of the Single Input Multi Output (SIMO) systems described by univariate polynomial matrices. The problem is equivalent to computing the nearest noncoprime polynomial matrix to the polynomial matrix describing the system in some prescribed norm. A particular case of this problem is to compute approximate GCD of univariate polynomials. Further this problem is shown to be equivalent to the Structured Low Rank Approximation (SLRA) of a linearly structured resultant matrix associated with the given polynomial matrix. The radius of controllability is then computed by finding the nearest SLRA of this resultant matrix.**

17.00 – 17.30

Computing the Controllability Radius for Higher Order Systems Using Semidefinite Programming
*Bogdan C. Şicleru, Bogdan Dumitrescu*

***Abstract***–**We propose here a new approach for computing the controllability radius for higher order systems. The original problem is restated as an eigenvalue minimization problem and further transformed into a semidefinite programming problem. We then relax our problem by imposing a sum-of-squares constraint. Experimental results show that our algorithm can obtain good results in a much smaller computation time than the existing algorithm.**

## New Results on Computation and Control
*(Invited Session)*

**Room 11**

***Organizer:*** *Bijoy K. Ghosh*
***Chair:*** *Bijoy K. Ghosh*

15.30 – 16.00

Periodic and Recursive Control Theoretic Smoothing Splines
*Maja Karasalo, Xiaoming Hu, Clyde F. Martin*

***Abstract***–**In this paper, a recursive control theoretic smoothing spline approach is proposed for reconstructing a closed contour. Periodic splines are generated by minimizing a cost function subject to constraints imposed by a linear control system. The optimal control problem is shown to be proper, and sufficient optimality conditions are derived for a special case of the problem using Hamilton-Jacobi-Bellman theory.**

**The filtering effect of the smoothing splines allows for usage of noisy sensor data. An important feature of the method is that several data sets for the same closed contour can be processed recursively so that the accuracy is improved stepwise as new data becomes available.**

16.00 – 16.30

Smoothing Splines on the Torus
*F. Egebrand, Magnus Egerstedt, Clyde F. Martin*

***Abstract***–**An algorithm is presented for constructing smoothing splines on the torus. The algorithm uses a particular representation of the torus and is suboptimal. However it produces good trajectories and among all possible smoothing spline it does very well in terms of the cost function.**

16.30 – 17.00

Control Aspects of a Finite Length Hubbard Chain
*F. Assaad, Gunther Dirr, F. Goth, Uwe Helmke*

***Abstract***–**Solid state physics provides a rather new application area for quantum control. Yet, the high dimensional state spaces in this field require a thorough analysis of the underlying Lie algebraic structures for developing efficient control strategies. In this paper, we focus a one-dimensional chain of quantum dots described by the Hubbard model. The model plays an extremely important role in solid state physics since it is the simplest model which explicitly takes into account the interplay between Coulomb repulsion of electrons and their kinetic energy. We begin with an comprehensive description to the mathemtical tools need for the appropriate state space construction. Based on these concepts, we introduce the general Hubbard Hamiltonian and discuss some aspects of is general Lie algebraic structure. Finally, we present a toy example for illustrating the afore established notions.**

**The tutorial part of this work is supposed to enhance the collaboration between theoretical physicists and mathematicians in the area of quantum control.**

17.00 – 17.30

To Tilt Your Head or Not To: Potentially
*Bijoy K. Ghosh, Indika B. Wijayasinghe*

***Abstract***–**In this paper we study the human head movement, when the head shifts its orientation between two possible heading directions, as a simple mechanical control system. Head movements obey Donders' constraint (as opposed to the Listing's constraint for eye movement), which states that the allowed orientations of the head are obtained by rotating a fixed 'primary heading direction' by a subclass of rotation matrices. These rotation matrices have their axes of rotation restricted to a fixed surface, called the Donders' surface. Donders' Law states that when head moves spontaneously from left to right and back or from top to bottom and back, the head rotation matrix has no torsional component. On the other hand, when the head moves diagonally from the top left to the bottom right and back or from the top right to the bottom left and back, spontaneously, the axis of rotation has a small torsional component. The torsional component effectively rotates the head with respect to the frontal line of 'heading'. The head appears slightly tilted as a result of the slight torsion. Defining a suitable Riemannian metric, we study dynamic control of head movement when the head orientations satisfy the Donders' constraint throughout its entire trajectory. Head movements are actuated by choosing a suitable potential function and the oscillations are damped by adding a suitable damping term. An important result of this paper is to show the effect of the torsional component as head is allowed to move between two 'headings'. We show that when the peak value of the allowable torsion is high, i.e. when the head is allowed to be more tilted, transition time between two headings is shortened.**

## Interpolation and Approximation in Linear Systems – 2
*(Invited Session)*

**Room 12**

***Organizers:*** *Andrea Gombani, Martine Olivi*
***Chair:*** *Martine Olivi*

15.30 – 16.00

Parametrization of Matrix-Valued Lossless Functions Based on Boundary Interpolation
*Ralf Peeters, Martine Olivi, Bernard Hanzon*

***Abstract***–**This paper is concerned with parametrization issues for rational lossless matrix valued functions. In the same vein as previous works, interpolation theory with metric constraints is used to ensure the lossless property. We consider here boundary interpolation and provide a new parametrization of balanced canonical forms in which the parameters are angular derivatives. We finally investigate the possibility to parametrize orthogonal wavelets with vanishing moments using these results.**

16.00 – 16.30

On the Partial Realization Problem
*Andrea Gombani, György Michaletzky*

***Abstract***–**We consider here a two sided interpolation problem where we want to minimize the degree of the interpolant. We show that this degree is given by the rank of a particular solution to a Sylvester equation which, in some particular cases becomes a Löwner or a Hankel matrix. We consider an application to the usual partial realization problem. The results are quite general and no particular assumption on the location of the interpolating nodes are needed.**

16.30 – 17.00

On Tangential Matrix Interpolation
*Paul A. Fuhrmann*

***Abstract***–**The talk will present an algebraic approach, using polynomial and rational mod- els over an arbitrary field, to tangential interpolation problems, both by polynomial as well as rational functions. Appropriate extensions of scalar problems, associated with the names of Lagrange (first order), Hermite (high order) and Newton (recur- sive) are derived. The relation of tangential matrix interpolation problems to the matrix Chinese remainder theorem are clarified. Some two sided interpolation prob- lems are dealt using the theory of tensored models. The polynomial results are then used as a basis for the solution of the corresponding problems of interpolation by rational matrix functions. We shall also try to explain the role of tensored models in the study of the polynomial version of the Sylvester equation and its connection to model reduction by interpolation.**

17.00 – 17.30

Polynomial Structure of 3 x 3 Reciprocal Inner Matrices
*David Avanessoff, Martine Olivi, Fabien Seyfert*

***Abstract***–**The objective of our work is the derivation of efficient algorithms for the synthesis of microwave multiplexers. In our opinion, an efficient frequency design process calls for the understanding of the structure of n x n inner (or lossless) reciprocal rational functions for n > 2. Whereas the case n = 2 is completely understood and a keystone of filter synthesis very little seems to be known about the polynomial structure of such matrices when they involve more than 2 ports. We therefore start with the analysis of the 3 x 3 case typically of practical use in the manufacturing of diplexers. Based on recent results obtained on minimal degree reciprocal Darlington synthesis [6], we derive a polynomial model for 3 x 3 reciprocal inner rational matrices with given McMillan degree.**

## Passive Network Synthesis
*(Invited Session)*

**Room 13**

***Organizer:*** *Malcolm C. Smith*
***Chair:*** *Malcolm C. Smith*

15.30 – 16.00

Passive Synthesis of the Terminal Behavior of Circuits
*Jan C. Willems*

***Abstract***–**The synthesis of passive electrical circuits has had a profound influence in electrical engineering in general, and in systems theory in particular. The seminal result in this area is the 1932 theorem by Otto Brune in which it is proven that a transfer function is the driving point impedance of a 2-terminal one-port consisting of a finite number of passive resistors, inductors, capacitors, and transformers if and only if the transfer function is rational and positive real. The notion of positive realness was in fact first introduced in precisely this context. Later, Bott and Duffin showed that transformers are not needed. Brune's result was generalized to multi-ports, leading to the result that a transfer function is the driving point impedance of a multi-port consisting of a finite number of passive resistors, inductors, capacitors, transformers, and gyrators if and only if the transfer function is a positive real matrix of rational functions.**

**The importance of these results may be seen by the relevance of positive realness and dissipativity in essentially all areas of present-day control and systems theory. The aim of this presentation is to examine some aspects of the classical synthesis question. In another presentation (entitled "Ports and Terminals") in this conference, we explain that the description**

of circuits with a finite number of external wires through which the circuit interacts with its environment leads to a multi-terminal description, rather than to a multi-port description. In addition, there is subtle difference, related to controllability and common factors, between the impedance of a circuit versus a specification of the external behavior. We pose the synthesis problem of circuits in terms of a terminal description. Necessary and sufficient conditions are given for the terminal behavior of a circuit consisting of an interconnection of positive resistors. In its simplest form, these conditions require that the matrix that relates the voltage vector to the current vector be symmetric hyperdominant with zero excess. This result is readily generalized to circuits containing only inductors and capacitors. Other cases will be discussed as well. Finally, we examine the subtle difference between synthesizing a linear time-invariant differential behavior versus synthesizing a transfer function. We show that the classical synthesis results apply only to controllable behaviors, but that the synthesis of non-controllable systems is basically an open area. In fact, the classical Bott-Duffin result realizes a given transfer function in a non-controllable fashion. This implies that the transformerless synthesis of a controllable linear time-invariant differential one-port behavior remains an open question.

16.00 – 16.30

Redundancies in Transformerless Network Synthesis
*Jason Zheng Jiang, Malcolm C. Smith*

***Abstract***–**The purpose of this paper is to give a compact summary of recent results based on the concept of a regular positive-real function. We will list an efficient set of networks which is capable of realising all biquadratics which are realisable by 5-element networks or 6-element networks of seriesparallel type. The structures are simpler than the full Bott- Duffin synthesis, though there are some (non-regular) positivereal biquadratics which cannot be realised by this class.**

16.30 – 17.00

Network Optimization and Synthesis Using a Combined Mechanical and Electrical System: Application to Vehicle Suspension Control
*Fu-Cheng Wang, Hsiang-An Chan*

***Abstract***–**This paper introduces a mechatronic network and applies it to vehicle suspensions for performance optimization. The mechatronic network consists of a ball-screw and permanent magnet electric machinery (PMEM), such that the system impedance is a combination of mechanical and electrical impedances. We then apply the network to vehicle suspensions, and demonstrate the performance benefits and their sensitivities to parameter variations. The optimal electrical impedances are constructed and experimentally verified. Based on the results, the mechatronic network is deemed effective.**

## New Mathematical Methods in Multidimensional Systems Theory – 1
*(Invited Session)*

**Room 14**

***Organizers:*** *Alban Quadrat, Thomas Cluzeau*
***Chair:*** *Alban Quadrat*

15.30 – 16.00

Further Results on Serre's Reduction of Multidimensional Linear Systems
*Mohamed S. Boudellioua, Alban Quadrat*

***Abstract***–**Serre's reduction aims at reducing the number of unknowns and equations of a linear functional system (e.g., system of ordinary or partial differential equations, system of differential time-delay equations, system of difference equations). Finding an equivalent representation of a linear functional system containing fewer equations and fewer unknowns generally simplifies the study of its structural properties, its closed-form integration and different numerical issues. The purpose of this paper is to present a constructive approach to Serre's reduction for linear functional systems.**

16.00 – 16.30

Serre's Reduction of Linear Partial Differential Systems Based on Holonomy
*Thomas Cluzeau, Alban Quadrat*

***Abstract***–**Given a linear functional system (e.g., an ordinary/ partial differential system), Serre's reduction aims at finding an equivalent linear functional system which contains fewer equations and fewer unknowns. The purpose of this paper is to study Serre's reduction of underdetermined linear systems of partial differential equations with analytic coefficients whose formal adjoints are holonomic in the sense of algebraic analysis. In particular, we prove that every analytic linear system of ordinary differential equations with at least one input is equivalent to a sole analytic ordinary differential equation.**

16.30 – 17.00

Purity Filtration of 2-Dimensional Linear Systems
*Alban Quadrat*

***Abstract*—** **The purpose of this paper is to show that every linear partial differential (PD) system defined by means of a matrix with entries in the noncommutative polynomial ring $D = A\langle\partial_1, \ldots, \partial_n\rangle$ of PD operators in $\partial_1 = \frac{\partial}{\partial x_1}, \ldots, \partial_n = \frac{\partial}{\partial x_n}$ with coefficients in a differential ring $A$, which satisfies certain regularity conditions, is equivalent to a linear PD system defined by an upper triangular matrix of PD operators formed by three diagonal blocks: the first (resp., second) diagonal block defines a $\dim(D)$-dimensional (resp., $\dim(D)-1$-dimensional) linear PD system and the third one defines a linear PD of dimension less or equal to $\dim(D)-2$. In particular, if $n = 2$, then the equivalent upper triangular matrix corresponds to the purity filtration of the finitely presented left $D$-module $M$ associated with the linear PD system. Moreover, repeating the same techniques with the linear PD system of dimension less or equal to $\dim(D)-2$, the purity filtration of $M$ can be obtained in the general case (i.e., $n \geq 2$). Finally, this equivalent form of the linear PD system can be used to obtain a Monge parametrization and for closed-form integration of linear PD systems.**

17.00 – 17.30

A Polynomial-Algebraic Approach to Lyapunov Stability Analysis of Higher-Order 2-D Systems
*Paolo Rapisarda, Kiyotsugu Takaba, Chiaki Kojima*

***Abstract***–**We introduce a four-variable polynomial matrix equation which plays an essential role in the stability analysis of discrete 2-D systems and in the computation of Lyapunov functions for such systems; we call this the 2-D polynomial Lyapunov equation (2-D PLE). We also give necessary and sufficient conditions for the stability of "square" 2-D systems based on solutions of the 2-D PLE satisfying additional properties.**

## Recent Developments in Multidimensional Systems, Control and Signals – Theory and Applications – 1
*(Invited Session)*

**Room 15**

***Organizer:*** *Krzysztof Gałkowski*
***Chair:*** *Krzysztof Gałkowski*

15.30 – 16.00

On a Nonlinear Two-Directionally Continuous Repetitive Process
*Marek Majewski*

***Abstract*–In the paper we consider a nonlinear, continuous version of the well-known discrete and differential repetitive process. A two-directionally linear continuous version of repetitive process has been introduced in paper [9]. The aim of this paper is to introduce a nonlinear version of the system considered in [9] and to prove the fundamental results for such systems: the existence, uniqueness and the continuous dependence of solutions on functional parameters (controls), as it has been obtained in [9] for the linear system.**

16.00 – 16.30

Controllability, Observability and Disturbance Attenuation by Boundary Control of Repetitive Processes with Smoothing
*Teresa Azevedo-Perdicoúlis, Gerhard Jank*

***Abstract*–In this paper, we present an explicit representation of solutions for a specific class of linear repetitive processes with smoothing. This representation then is used to obtain direct criteria for controllability and observability properties of this class of discrete time 2–D systems with delays. We not only consider classical controllability properties, where control is obtained by choosing the inhomogeneity appropriately, but also controllability of the system by steering the system through boundary data control. From the point of view of technical applications, for instance in high pressure gas network modelling (see [1]), it seems to be more reliable to consider boundary data controls. Therefore in this paper we emphasise boundary control properties of the system. A disturbed optimal boundary control problem with a quadratic criterion is also solved.**

16.30 – 17.00

On Asymptotically Reconstructing Local-State Trajectories for 2-D Systems without Exploiting Input Information
*Lorenzo Ntogramatzidis, Michael Cantoni*

***Abstract*–The notions of input-containing and detectability subspaces are developed within the context of observer synthesis for two-dimensional (2-D) Fornasini-Marchesini models. Specifically, the paper considers observers which asymptotically estimate the local state, in the sense that the error tends to zero as the reconstructed local state evolves away from possibly mismatched boundary values, modulo a detectability subspace. Ultimately, the synthesis of such observers in the absence of explicit input information is addressed.**

17.00 – 17.30

LQ Parametrization of Robust Stabilizing Static Output Feedback Controllers for 2D Continuous Roesser Systems
*Pavel V. Pakshin, Krzysztof Gałkowski, Eric Rogers*

***Abstract*–The paper considers robust control of 2D linear systems described by the Roesser model, where information propagation in each the independent directions is a function of a continuous variable, and an affine parallelotopic type model for uncertainty is assumed. Sufficient optimality conditions for the existence of an LQ state feedback controller are developed in the absence of model uncertainty and then used to characterize a set of stabilizing static output feedback controllers for this system in the presence of parameter uncertainties, resulting in non-convex conditions parameterized by the weighting matrices of a quadratic cost function. Replacing these conditions by convex approximations leads to an algorithm for computing the stabilizing gain matrix of the controller. The algorithm is non-iterative and uses computationally efficient SDP solvers. A numerical example is given to demonstrate the applicability and effectiveness of the algorithm.**

# Tuesday, 6 July

## Plenary Lecture

**Room 1**

***Chair:*** *Joseph A. Ball*

09.00 – 10.00

In memory of Christopher I. Byrnes
*Alberto Isidori, Joachim Rosenthal, Anders Lindquist, Giorgio Picci*

## Distributed Parameter Systems I: System Structure
*(Invited Session)*

**Room 1**

***Organizers:*** *Birgit Jacob, Michael A. Demetriou, Miroslav Krstic, Kirsten Morris, Hans Zwart*
***Chair:*** *Birgit Jacob*

10.30 – 11.00

Second-Order Systems with Acceleration Measurement
*Birgit Jacob, Kirsten Morris*

***Abstract*–A number of systems are modelled by partial differential equations that include second-order derivatives with respect to time. Flexible structures, acoustic waves in cavities as well as coupled acoustic-structure systems are examples of systems modelled by equations of this type. Accelerometers are a very popular choice of sensor for these systems. The systems theory for acceleration systems has not been well-studied. In this talk, conditions under which these systems are well-posed are established. We obtain a representation for the input/output map and transfer function for the situation where the control system may not be well-posed. We provide several examples to show that in general using acceleration as the output leads to an ill-posed system. We then develop a model for acceleration measurements that incorporates a model for the micro-electrical-mechanical systems (MEMS) devices used to measure acceleration. With this more complex model, the control system is in general well-posed with a natural choice of state space.**

11.00 – 11.30

Riesz Basis for Strongly Continuous Groups
*Hans Zwart*

***Abstract*–Given a Hilbert space and the generator of a strongly continuous group on this Hilbert space. If the eigenvalues of the generator have a uniform gap, and if the span of the corresponding eigenvectors is dense, then these eigenvectors form a Riesz basis (or unconditional basis) of the Hilbert space. Furthermore, we show that none of the conditions can be weakened.**

11.30 – 12.00

Optimal Control of Fractional Systems: a Diffusive Formulation
*Denis Matignon*

***Abstract*–Optimal control of fractional linear systems on a finite horizon can be classically formulated using the adjoint system. But the adjoint of a causal fractional integral or derivative operator happens to be an anti-causal operator: hence, the adjoint equations are not easy to solve in the first place. Using an equivalent diffusive realization helps transform the original problem into a coupled system of PDEs, for which the adjoint system can be more easily derived and properly studied.**

12.00 – 12.30

Infinite Structure for Infinite-Dimensional Systems: a Directional Approach
*Petteri Laakkonen, Seppo Pohjolainen*

***Abstract*–In this article structure at infinity of infinitedimensional linear time invariant systems with finitedimensional input and output spaces is discussed. It is shown that by appropriately restricting the paths approaching infinity and under certain majorization conditions a diagonal form that describes the behavior at infinity can be found. This diagonal form is a generalization of the Smith-McMillan form at infinity. It is then used to simplify certain solvability conditions of a regulation problem. Examples on time-delay and distributed parameter systems are given.**

## Probabilistic Methods
*(Regular Session)*

**Room 2**

***Chair:*** *Pavel Shcherbakov*

10.30 – 11.00

Boundary Oracles for Control-Related Matrix Sets
*Pavel Shcherbakov*

***Abstract*–This paper presents closed-form solutions for the problem of finding the points of intersection of a 1D line and the boundary of typical matrix sets encountered in control; specifically, those defined by linear matrix inequalities. This procedure is referred to as boundary oracle; it is the key technical component of various random walk algorithms exploited within the randomized approach to control and optimization. In the paper, several such oracles are devised and generalized to robust formulations where the coefficients of matrix inequalities are subjected to uncertainties.**

11.00 – 11.30

Potentials and Limitations to Speed up MCMC Methods Using Non-Reversible Chains
*Balázs Gerencsér*

***Abstract*–Mixing time is the quantity to measure the speed of MCMC sampling. We compare the cases of using reversible chains, which are better understood with non-reversible chains, which offer more degree of freedom. It turns out that nonreversible chains can provide significant speedup in some cases but no improvement in others.**

11.30 – 12.00

A Stochastic Paradox in a Model for Reflected Brownian Motion?
*Erik I. Verriest*

***Abstract*— This paper is pedagogical in nature. It is shown that a stochastic integral with respect to a Wiener process does not always yield a martingale. Consequently, ignoring the $\mathrm{d}w$ term in the calculation of expectations, as might be done in a first 'back-of-the-envelope' approach, can lead to false results. We develop a model for Brownian motion constrained to $x > 0$, for which the moments can be computed exactly. There is no paradox if one solves the problem correctly, however a "blind" application of the Itô calculus yields to the paradox that the variance may become negative. In order to put the student back on track, we close the paper by stating some sufficient conditions that guarantee that the stochastic integral is a true martingale.**

12.00 – 12.30

Distribution-Dependent Performance of the Good-Turing Estimator for the Missing Mass
*Mesrob I. Ohannessian, Munther A. Dahleh*

***Abstract*–The Good-Turing estimator for the missing mass has certain bias and concentration properties which define its performance. In this paper we give distribution-dependent conditions under which this performance can or cannot be matched by a trivial estimator, that is one which does not depend on observation. We introduce the notion of accrual function for a distribution, and derive our conditions from the fact that the latter governs the decay rate of the mean of the missing mass. These results shed light on the inner workings of the Good-Turing estimator, and explain why it applies particularly well for heavy-tailed distributions such as those that arise when modeling natural language.**

## Behaviors
*(Regular Session)*

**Room 3**

***Chair:*** *Paolo Rapisarda*

10.30 – 11.00

State Maps from Bilinear Differential Forms
*Paolo Rapisarda, Arjan J. van der Schaft*

***Abstract*–State equations need often to be constructed from a higher-order model of a system, resulting for example from the interconnection of subsystems, or from system identification procedures. In order to compute state equations it is crucial to choose a state variable. One way of doing this is through the computation of a state map, introduced in [4]. In this paper we develop an alternative approach to the algebraic characterization of state maps, based on the calculus of bilinear differential forms (BDFs), see [8]. From this approach stem a new algorithm for the computation of state maps, and some new results regarding symmetries of linear dynamical systems.**

11.00 – 11.30

On the Problem of Model Reduction in the Gap Metric
*Mark Mutsaers, Siep Weiland*

***Abstract*— This paper deals with the model reduction problem where, for a given linear time-invariant dynamical system of complexity $n$, a simpler system of complexity $r < n$ is desired such that the gap between their respective behaviors is minimized. We describe dynamical systems as closed, shift invariant subspaces of $\mathcal{H}_2^+$, represented as kernels of rational multiplicative operators that are anti-stable rational elements of $\mathcal{RH}_\infty^-$. Contrary to other approaches this enables to reduce autonomous behaviors. In this paper we will give upper- and lower bounds for the minimal gap between a rational behavior and its optimal approximation in this system class. Bounds are given in terms of its Hankel Singular Values. These bounds only depend on the given system and can be computed in advance due to the use of rational operators describing the dynamical systems. This will be illustrated by a simple example.**

11.30 – 12.00

The Behavioral Approach to Simultaneous Stabilization
*Osamu Kaneko*

***Abstract*–Simultaneous stabilization is the problem of finding a condition under which there exists a single controller that stabilizes multiple (which is denoted with N in this paper) plants. In this paper, we address the problem of simultaneous stabilization in the behavioral framework. First, we provide a new equivalent condition for a pair of linear systems to be simultaneously stabilizable. We then also present a representation of simultaneous stabilizers under the assumption that the interconnection of these two behavior is stable. By using this result, we address to derive a condition under which a set of three linear behaviors is simultaneously stabilizable. In this case, we show that: if one of the three behaviors stabilizes the other two behaviors, then a set of these three behaviors are simultaneously stabilizable. Moreover, a representation for simultaneous stabilizer in this case is also presented under this assumption.**

12.00 – 12.30

Deterministic Identification of Lossless and Dissipative Systems
*Paolo Rapisarda, Harry Trentelman*

***Abstract*–We illustrate procedures to identify a state-space representation of a passive or bounded-real system from noisefree measurements. The basic idea underlying our algorithms is to obtain a state sequence from a rank-revealing factorization of a Gramian-like matrix constructed from the data. The computation of state-space equations is then performed solving a system of linear equations, similarly to what happens in classical deterministic subspace identification methods.**

12.30 – 13.00

Passive Behaviors and their Passive State/Signal Realizations in Continuous Time
*Damir Z. Arov, Mikael Kurula, Olof J. Staffans*

***Abstract*— In this talk we discuss passive and conservative state/signal systems in continuous time. Such systems can be used to model, e.g., a passive linear electrical circuit containing lumped and/or distributed resistances, capacitors, inductors, and wave guides, etc. Most of the standard partial differential equations appearing in physics on can be written in state/signal form.**

**A passive state/signal system $\Sigma = (V; \mathcal{X}, \mathcal{W})$ consists of three components: 1) an internal Hilbert *state space* $\mathcal{X}$, 2) a Kreĭn *signal space* $\mathcal{W}$ through which the system interacts with the external world, and 3) a *generating subspace* $V$ of the product space $\mathcal{X} \times \mathcal{X} \times \mathcal{W}$. The generating subspace is required to be maximal nonnegative with respect to a certain power inner product and to satisfy an extra non-degeneracy condition.**

## Sigma-Delta Modulators
*(Invited Session)*

**Room 4**

***Organizer:*** *Paolo Rapisarda*
***Chair:*** *Paolo Rapisarda*

10.30 – 11.00

Incremental Data Converters
*Gabor C. Temes, Yan Wang, Wenhuan Yu, Janos Markus*

***Abstract*–Incremental data converters (IDCs) are high-accuracy oversampled analog-to-digital converters (ADCs). They form a special subclass of the commonly used delta-sigma ADCs. Unlike the latter, IDCs are only operated intermittently, typically for a few hundred clock periods, and hence they possess only a finite memory. They offer advantages in high accuracy, stability, absence of idle tones, low power dissipation, and ease of multiplexing. Hence, they are often used in sensor and MEMS interfaces.**

**In this paper, some recent results on the theory and design of IDCs are discussed, and illustrated with the description of a recently implemented data converter.**

11.00 – 11.30

A Constraint in Single-Feedback Sigma Delta Force-Feedback Loops with a Discrete-Time Loop Filter
*Pieter Rombouts, Johan Raman, Ludo Weyten*

***Abstract*–In this tutorial paper we review Sigma Delta force feedback for the read-out of Micro-Electro-Mechanical (MEMS) inertial sensors with a discrete time loop filter. First we focus on the single feedback structure (with only mechanical feedback). It is shown that in this situation the mechanical transfer function introduces a zero in the overall loop gain. This gives rise to a constraint in the realizable NTF. In theory this can be overcome by adding a pole to the controller. An alternative solution is to add an extra electrical feedback branch. The latter solution is considered more beneficial in terms of power consumption and chip area.**

11.30 – 12.00

Quantization Noise Conditioning Techniques for Digital Delta-Sigma Modulators
*Sudhakar Pamarti*

***Abstract*–This paper presents an overview of outstanding theoretical problems in delta-sigma modulator based electronic digital-to-analog circuits and outlines quantization noise conditioning techniques that are being employed to address these problems. Both the problems and the conditioning techniques are described in the context of a special class of electronic circuits called frequency synthesizers.**

12.00 – 12.30

Dynamics-Level Design for Discrete- and Continuous-Time Band-Pass Sigma-Delta-Modulators for Micro-Machined Accelerometers
*Jian Luo, Paolo Rapisarda, Michael Kraft*

***Abstract*— High-performance micro-electro-mechanical systems (MEMS) sensors can be implemented by incorporating a micro-machined capacitive sensing element in a Sigma-Delta-Modulators ($\Sigma\Delta M$) force-feedback loop, forming an electro-mechanical $\Sigma\Delta M$ ($EM - \Sigma\Delta M$). We propose a transfer-function based design methodology to realize discrete- and continuous-time low-pass electro-mechanical $\Sigma\Delta M$ systems. The design is performed at the level of the integrated system consisting of the electro-mechanical sensor and of the electronic circuit; we call this the *dynamics-level*. We also illustrate a technique to perform the conversion of the discrete-time design to a continuous-time one. The approach is demonstrated through an electro-mechanical $\Sigma\Delta M$ design example for a bulk micro-machined, capacitive accelerometer.**

## Noncommutative Rational Functions and Noncommutative Convexity – 1
*(Mini-Course)*

**Room 6**

***Organizers:*** *William J. Helton, Dmitry S. Kaliuzhnyi-Verbovetskyi, Igor Klep, Victor Vinnikov*

10.30 – 12.30

Noncommutative Rational Functions and Noncommutative Convexity
*William J. Helton, Dmitry S. Kaliuzhnyi-Verbovetskyi, Igor Klep, Victor Vinnikov*

***Abstract*–One of the biggest recent revolutions in optimization, called semidefinite programming, is a methodology for solving Linear Matrix Inequalities (LMIs) proposed in 1994 by Nesterov and Nemirovski. As it turns out, most optimization problems appearing in systems and control are dimensionindependent. Namely, the natural variables are matrices (rather than just collections of scalars) and the problem involves rational expressions in these matrix variables which have therefore the same form independent of the matrix sizes. Hence the study of LMIs in systems and control leads not so much to classical convex analysis and positivity, but rather to the newly emerging areas of (free) noncommutative convexity and noncommutative positivity, with the polynomials and rational functions in commuting variables replaced by noncommutative polynomials and noncommutative rational functions. The purpose of this minicourse is to provide an introduction to noncommutative rational functions and their realization theory on one hand, and to noncommutative positivity and noncommutative convexity, including noncommutative LMIs, on the other.**

## Multi-Agent Systems
*(Regular Session)*

**Room 7**

***Chair:*** *Magnus Egerstedt*

10.30 – 11.00

Sustainable Group Sizes for Multi-Agent Search-and-Patrol Teams
*Musad Haque, Magnus Egerstedt, Clyde F. Martin*

***Abstract*–We identify sustainable sizes for a multi-agent system that consists of two classes of agents: one class is responsible for searching an area; the other for providing perimeter security for that area. In this context, sustainability means the ability of the system to accomplish the task while balancing shared resources. Bio-inspired rules based on the pride structures of African lions are developed to determine the sustainability of a group size.**

11.00 – 11.30

Dynamic Spectral Clustering
*Amy LaViers, Amir Rahmani, Magnus Egerstedt*

***Abstract*–Clustering is a powerful tool for data classification; however, its application has been limited to analysis of static snapshots of data which may be time-evolving. This work presents a clustering algorithm that employs a fixed time interval and a time-aggregated similarity measure to determine classification. The fixed time interval and a weighting parameter are tuned to the system's dynamics; otherwise the algorithm proceeds automatically finding the optimal cluster number and appropriate clusters at each time point in the dataset. The viability and contribution of the method is shown through simulation.**

11.30 – 12.00

Bounds and Approximations on the Reliability of Large Networks
*Tamás Szántai, József Bukszár, Edith Kovács*

***Abstract*–We present methods for calculating bounds and approximations on the reliability of large networks. We regard the most reliable few paths leading from the start node to the terminal node of the network and then calculate lower and upper bounds on the probability that at least one of these paths is permeable. For this purpose we will use the so called multitree upper and hypermultitree lower bounds on the probability of union of events, developed earlier by J. Bukszár. Chow- Liu's dependence tree approximation of multivariate discrete probability distributions was generalized earlier by T. Szántai and E. Kovács to higher order dependence tree approximations, called k-th order t-cherry junction tree approximations. We will show how the Chow-Liu's dependence tree and the more general t-cherry junction tree graph structures can be used for bounding and approximating the network reliability. Some possible applications and numerical results will also be presented.**

12.00 – 12.30

On the Geometry and Deformation of Switching Manifolds for Autonomous Hybrid Systems
*Farzin Taringoo, Peter E. Caines*

***Abstract*–This paper provides a geometrical analysis of autonomous hybrid optimal control systems (HOCS) by studying the properties of switching manifolds in Euclidean space and their associated optimal hybrid trajectories. Motivational examples are to be found in the speed dependent operation of automatic gear shift systems of heavy trucks [1]. In this paper the mathematical formulation of a hybrid system is presented and then the Hybrid Maximum Principle (HMP) necessary conditions for the optimality of a hybrid system trajectory are given, (see [6],[7]). Second order optimality conditions are given in terms of the Hessian matrix of the value function and geometrical data involving the curvature of the switching manifold at its intersection with an optimal trajectory. At the end, the energy of a switching manifold deformation mapping is defined and the hybrid cost optimization is performed with respect to such deformation mappings.**

## Recent Developments in Multidimensional Systems, Control and Signals – Theory and Applications – 2
*(Invited Session)*

**Room 8**

***Organizer:*** *Krzysztof Gałkowski*
***Chair:*** *Krzysztof Gałkowski*

10.30 – 11.00

Existence of Optimal Solutions of Two-Directionally Continuous Repetitive Process under Convexity Assumption
*Marek Majewski*

***Abstract*–In the paper a sufficient condition for the existence of optimal solution to the optimal control problem governed by two-directionally continuous repetitive process and the integral cost functional is given. In the main theorem the crucial assumption is the convexity of the so-called generalized velocities set. The proof of the main theorem is based on the lower closure theorem.**

11.00 – 11.30

Distributed Stabilization of Spatially Invariant Systems: Positive Polynomial Approach
*Petr Augusta, Zdeněk Hurak*

***Abstract*–The paper gives a computationally feasible characterisation of spatially distributed discrete-time controllers stabilising a spatially invariant system. This gives a building block for convex optimisation based control design for these systems. Mathematically, such systems are described by partial differential equations with coefficients independent on time and location. In this paper, a situation with one spatial and one temporal variable is considered. Models of such systems can take a form of a 2-D transfer function. Stabilising distributed feedback controllers are then parametrised as a solution to the Diophantine equation ax + by = c for a given stable bivariate polynomial c. This paper brings a computational characterisation of all such stable 2-D polynomials exploiting the relationship between a stability of a 2-D polynomial and positiveness of a related polynomial matrix on the unit circle. Such matrices are usually bilinear in the coefficients of the original polynomials. It is shown that a factorisation of the Schur-Cohn matrix enables linearisation of the problem, at least in a special instance of first-order systems. Then the computational framework of linear matrix inequalities and semidefinite programming can be used to describe the stability regions in the parameter space using a convex constraint.**

11.30 – 12.00

An Output Control of a Class of Discrete Second-order Repetitive Processes
*Pawel Dabkowski, Krzysztof Gałkowski, Biswa Datta*

***Abstract*–This paper presents new computationally efficient LMI results on stability and feedback stabilization for a class of ill-conditioned discrete, linear second-order repetitive processes, including the uncertain case. The results are derived via transformation of the second-order system to an equivalent first-order descriptor system, thus avoiding the necessity of inversion of an ill-conditioned leading coefficient matrix of the system, which is allowed also to be uncertain. This last feature, as frequently occurs, is of a great significance but the known approaches do not provide the easy way to solve this problem.**

12.00 – 12.30

Approximation of *N*D Systems with Multiple Dependent Variables
*Femke van Belzen, Siep Weiland*

***Abstract*–Multi-variable distributed systems describe the evolution of multiple dependent variables over a domain of independent variables. This paper considers model reduction for this type of systems. The method of Proper Orthogonal Decompositions (POD) is adapted using concepts from tensors and tensor decompositions. The result is a model reduction framework that is applicable to systems with an arbitrary number of dependent and independent variables.**

## Stability and Switching
*(Regular Session)*

**Room 9**

***Chair:*** *Vahid S. Bokharaie*

10.30 – 11.00

On the D-Stability of Linear and Nonlinear Positive Switched Systems
*Vahid S. Bokharaie, Oliver Mason, Fabian Wirth*

***Abstract*–We present a number of results on D-stability of positive switched systems. Different classes of linear and nonlinear positive switched systems are considered and simple conditions for D-stability of each class are presented.**

11.00 – 11.30

On the Stabilizability of Discrete-Time Positive Switched Systems
*Ettore Fornasini, Maria Elena Valcher*

***Abstract*–In this paper we consider the class of discretetime systems switching between an arbitrary number p of autonomous positive subsystems. Necessary and sufficient conditions for the existence of (either linear or quadratic) copositive Lyapunov functions, whose values can be decreased in every positive state, by suitably choosing one of p subsystems, are obtained. When these conditions are fulfilled, state-dependent switching strategies, which prove to be stabilizing, can be adopted. Finally, the performances of these Lyapunov based strategies are compared.**

11.30 – 12.00

Stability Criteria for Planar Linear Systems with State Reset
*Svetlana Polenkova, Jan Willem Polderman, Rom Langerak*

***Abstract*–In this work we perform a stability analysis for a class of switched linear systems, modeled as hybrid**

automata. We deal with a switched linear planar system, modeled by a hybrid automaton with one discrete state. We assume the guard on the transition is a line in the state space and the reset map is a linear projection onto the x-axis. We define necessary and sufficient conditions for stability of the switched linear system with fixed and arbitrary dynamics in the location.

12.00 – 12.30

On the Preservation of Co-Positive Lyapunov Functions under Padé Discretization for Positive Systems

*Annalisa Zappavigna, Patrizio Colaneri, Stephen Kirkland, Robert Shorten*

***Abstract*–In this paper the discretization of switched and non-switched linear positive systems using Padé approximations is considered. We show:**

**1) diagonal Padé approximations preserve both linear and quadratic co-positive Lyapunov functions;**

**2) positivity need not be preserved even for arbitrarily small sampling time for certain Padé approximations. Sufficient conditions on the Padé approximations are given to preserve positivity of the discrete-time system. Finally, some examples are given to illustrate the efficacy of our results.**

## Algebraic Structures – 1

*(Regular Session)*

**Room 10**

***Chair:*** *Néstor Thome*

10.30 – 11.00

Nonnegativity of Descriptor Systems of Index 1

*Alicia Herrero, Francisco J. Ramirez, Néstor Thome*

***Abstract*—In [S.K. Jain, J. Tynan, Nonnegative matrices $A$ with $AA^{\#} \geq O$. Linear Algebra & Appl. 379, 2004], the authors gave a characterization of nonnegative matrices $A$ such that $AA^{\#}$ is a nonnegative matrix, where $A^{\#}$ denotes the group inverse of the square matrix $A$. The product $AA^{\#}$ will be called the group-projector of the matrix $A$. Later, a slightly simplified characterization of the above result was presented in [A. Herrero, F. J. Ramírez, and N. Thome, Characterization of matrices with nonnegative group-projector. Lecture Notes in Control and Information Sciences 389, 2009]. In this paper, we present an application of the group-projectors to obtain the nonnegativity of control descriptor systems of index 1. This work improves some previous results in the literature in the sense that the nonnegativity of the coefficient matrix of the descriptor system is removed. So, we can apply this result to a wider class of systems in order to study its nonnegativity.**

11.00 – 11.30

Approximation of Non-Negative Integer-Valued Matrices with Application to Hungarian Mortality Data

*Márton Ispány, György Michaletzky, Jenő Reiczigel, Gábor Tusnády, Paula Tusnády, Katalin Varga*

***Abstract*–Singular valued decomposition (SVD) is a commonly applied technique for dimensionality reduction. SVD implicitely minimizes an unweighted sum of squares which may be inappropriate in several practical applications. This paper gives generalizations of SVD to other loss functions, e.g., weighted Frobenius distance and logistic loss, that are better suited to the data. We describe algorithms for minimizing these loss functions, and give an application to Hungarian mortality data.**

11.30 – 12.00

Explicit Parameterization of All Solutions of Linear Periodic Systems with Real-Valued Coefficients

*Ichiro Jikuya, Ichijo Hodaka*

***Abstract*–An extension is introduced to the recently introduced representation for linear periodic systems with realvalued coefficients. In order to parameterize all state transition matrices, a state transition matrix is factored as a multiplication of a T-periodic real-valued factor and two real-valued matrix exponential functions. By solving the matrix equations which give an implicit parameterization, we study the block structure of those factors and propose an explicit parameterization. We also study the corresponding block structure in the coefficient matrices of the systems.**

12.00 – 12.30

Factorizations for Some Classes of Matrices Related to Positivity

*Juan M. Peña*

***Abstract*–We descrtibe factorizations for some classes of matrices related to positivity and important in applications. The classes of matrices considered include nonsingular Mmatrices (matrices with nonpositive off-diagonal entries with positive inverse) and totally nonnegative matrices (matrices with all minors nonnegative). The considered factorizations include rank revealing factorizations, LDU-factorization, QRfactorization and symmetric-triangular factorization. Applications of these factorizations are presented.**

## Stability and Dissipativity

*(Regular Session)*

**Room 11**

***Chair:*** *Masaki Ogura*

10.30 – 11.00

Dissipativity of Pseudorational Behaviors

*Masaki Ogura, Yutaka Yamamoto*

***Abstract*–This paper studies dissipativity for a class of infinite-dimensional systems, called pseudorational, in the behavioral context. First a basic equivalence condition for average nonnegativity of quadratic differential forms induced by distributions is established as a generalization of the finitedimensional counterpart. For its proof, we derive a new necessary and sufficient condition for entire functions of exponential type (in the Paley-Wiener class) to be symmetrically factorizable. Utilizing these results we then study dissipativity of pseudorational behaviors. An example is given to illustrate results.**

11.00 – 11.30

Cyclodissipativity and Power Factor Improvement for Full Nonlinear Loads

*Dunstano del Puerto-Flores, Romeo Ortega, Jacquelien M.A. Scherpen*

***Abstract*–In recent research, a cyclodissipativity characterization of the problem of power factor compensation (PFC) for nonlinear loads with non-sinusoidal source voltage has been presented. Using this characterization the classical capacitor and inductor compensators can be interpreted in terms of energy equalization. This brief note focuses on the extension of this approach. In particular, one result is to show that power factor compensation is equivalent to a new cyclodissipativity condition. Another result is to consider general lossless linear filters as compensators and to show that the power factor is improved if and only if a certain**

**equalization condition between the weighted powers of inductors and capacitors of the nonlinear load is ensured.**

11.30 – 12.00

On Copositive Lyapunov Functions for a Class of Monotone Systems
*Björn S. Rüffer, Christopher M. Kellett, Peter M. Dower*

***Abstract*–This paper considers several explicit formulas for the construction of copositive Lyapunov functions for global asymptotic stability with respect to monotone systems evolving in either discrete or continuous time. Such monotone systems arise as comparison systems in the study of interconnected large-scale nominal systems. A copositive Lyapunov function for such a comparison system can then serve as a prototype Lyapunov functions for the nominal system. We discuss several constructions from the literature in a unified framework and provide sufficiency criteria for the existence of such constructions.**

12.00 – 12.30

Stability of Fluid Network Models and Lyapunov Functions
*Michael Schönlein, Fabian Wirth*

***Abstract*–We consider the class of closed generic fluid networks (GFN) models. This class contains for example fluid networks under general work-conserving and priority disciplines. Within this abstract framework a Lyapunov method for stability of GFN models was proposed by Ye and Chen. They proved that stability of a GFN model is equivalent to the property that for every path of the model a Lyapunov like function is decaying. In this paper we construct state-dependent Lyapunov functions in contrast to pathwise functionals. We first show by counterexamples that closed GFN models do not provide sufficient information that allow for a converse Lyapunov theorem with state-dependent Lyapunov functions. To resolve this problem we introduce the class of strict closed GFN models by forcing the closed GFN model to satisfy a concatenation and a perfectness condition and define a statedependent Lyapunov function. We show that for the class of strict closed GFN models a converse Lyapunov theorem holds. Finally, it is shown that common fluid network models, like general work-conserving and priority fluid network models as well as certain linear Skorokhod problems define strict closed GFN models.**

## Mechanical Systems
*(Regular Session)*

**Room 12**

***Chair:*** *Yoshiro Fukui*

10.30 – 11.00

Real-Time Obstacle Avoidance of a Two-Wheeled Mobile Robot via the Minimum Projection Method
*Yoshiro Fukui, Hisakazu Nakamura, Hirokazu Nishitani*

***Abstract*–This paper considers real-time obstacle avoidance control of a two-wheeled nonholonomic mobile robot. In this paper, we propose a discontinuous asymptotic stabilizing state feedback control law for a real-time obstacle avoidance problem via the minimum projection method. The method guarantees asymptotic stability and reduces the computational cost. The effectiveness of the proposed method is comfirmed by experiments.**

11.00 – 11.30

Dynamics and Control of 2D SpiderCrane: a RHC Approach
*Atul K. Kamath, Faruk Kazi, Navdeep M. Singh*

***Abstract*–In this paper we present modeling and control of a multicable suspended mechanism called the '2D Spider-Crane'. A spidercrane does not have any conventional heavy components and makes use of cables by virtue of which high transfer speeds are achievable. The initial part of the paper addresses the modeling of the mechanism, where the cable and pulley dynamics are separated, and the payload is viewed as a pendulum suspended from a cable whose suspension point lies on a mass that moves in a two-dimensional space. Using the Receding Horizon Control (RHC) strategy a trajectory tracking controller is proposed. Simulations were carried out in MATLAB.**

11.30 – 12.00

Sampled-Data Cross-Track Control for Underactuated Ships
*Hitoshi Katayama*

***Abstract*–The sampled-data cross-track control problem for an underactuated three degree-of-freedom ship is considered. A line-of-sight guidance algorithm is used to design surge and yaw control laws which make a ship track a desired straightline reference trajectory while maintaining a desired nonzero constant forward speed. Then applying the nonlinear sampleddata control theory and the stability theory of parametrized discrete-time cascade interconnected systems, it is shown that sampled-data cross-track is achieved by the designed control laws. Simulation results are also given to illustrate the design method.**

12.00 – 12.30

Intelligent Multiple AUV Path Planning
*P.B. Sujit, João de Sousa, Bernardo Maciel*

***Abstract*–One of the primary requirements of autonomous underwater vehicle (AUV) navigation is obstacle avoidance capability. Currently, AUVs have obstacle avoidance capability, however, they do not have intelligence to decide if narrow passages are safe for navigation or not. The AUVs update their location using inertial navigation method continuously which accumulates error with time. In order take the position deviation of the vehicle into account we use reach sets that defines safe region for the AUV. Determining reach set for a given time horizon is computationally intensive, therefore we use ellipsoidal toolbox that can provide approximate reach set for a given computational time interval. In this paper, we develop an intelligent path planner for autonomous underwater vehicles navigating in a rough terrain with limited sensing and communication capability using reach sets based on ellipsoidal toolbox. Later, we describe how the information can be shared between vehicles using micro-modems to accurately map the region and cooperatively assign those regions that are not covered. We present simulation results to show how the regions can be cooperatively explored and also study effect of sensing range, communication range and number of vehicles through Monte-Carlo simulations.**

## Moment Problems, Maximum Entropy, and Covariance Extension
*(Invited Session)*

**Room 13**

***Organizer:*** *Giorgio Picci*
***Chair:*** *Giorgio Picci*

10.30 – 11.00

A Maximum Entropy Approach to the Covariance Extension Problem for Reciprocal Processes
*Francesca Carli, Augusto Ferrante, Michele Pavon, Giorgio Picci*

***Abstract*–This paper addresses the problem of completing a partially specified symmetric matrix, where the specified entries lie on a single band centered on the main diagonal, in such a way that the completed matrix is positive definite, blockcirculant and with a banded inverse. This particular completion has the meaning of the covariance matrix of a reciprocal process stationary on the discrete circle $Z_N$. This problem, called the block-circulant band extension problem, arises in the context of maximum likelihood identification for such processes. This paper shows that the *block-circulant band extension problem* can in fact be solved as a maximum entropy problem. Indeed, the constraint that the inverse be banded can be removed with a considerable theoretical and computational simplification, as the maximum entropy block-circulant extension can be shown to always enjoy this property. Conditions for the feasibility of the problem are also provided.**

11.00 – 11.30

On the Factorization Approach to Band Extension of Block-Circulant Matrices
*Francesca Carli, Giorgio Picci*

***Abstract*— The following problem occurs in modeling and estimation of stationary processes defined on a finite interval $[1, N]$ of the integer line: complete a given finite sequence $\Sigma_0, \ldots, \Sigma_n$; $n < N$, of covariance matrices to form a symmetric block-Toeplitz matrix which has a *banded symmetric block-circulant* inverse of bandwidth $n$. This is a matrix band extension problem which does not seem to have been considered before. It looks apparently alike the classical block-Toplitz band extension problem for covariance matrices on $\mathbb{Z}$. We show that it cannot be approached by the standard factorization techniques used in the literature to do band extension for Toeplitz matrices.**

11.30 – 12.00

Graphical Models of Autoregressive Moving-Average Processes
*Enrico Avventi, Anders Lindquist, Bo Wahlberg*

***Abstract*–Consider a Gaussian stationary stochastic vector process with the property that designated pairs of components are conditionally independent given the rest of the components. Such processes can be represented on a graph where the components are nodes and the lack of a connecting link between two nodes signifies conditional independence. This leads to a sparsity pattern in the inverse of the matrix-valued spectral density. Such graphical models find applications in speech, bioinformatics, image processing, econometrics and many other fields, where the problem to fit an autoregressive (AR) model to such a process has been considered. In this paper we take this problem one step further, namely to fit an autoregressive moving-average (ARMA) model to the same data. We develop a theoretical framework which also spreads further light on previous approaches and results.**

12.00 – 12.30

On the Maximum Entropy Completion of Circulant Covariance Matrices
*Francesca Carli, Tryphon T. Georgiou*

***Abstract*–This paper deals with the positive-definite completion of partially specified (block-) circulant covariance matrices. In the absence of any constraint other than positivity, the maximal-determinant completion of a partially specified covariance matrix (i.e., the so-called maximum entropy completion) was shown by Dempster to have an inverse with zero-values at all locations where the original matrix was unspecified–this will be referred to as the Dempster property. In earlier work, Carli etal. [2] showed that even under the constraint of a covariance being block-circulant, as long as the unspecified elements are in a single band, the maximum entropy completion has the Dempster property. The purpose of the present paper is to prove that circulant, block-circulant, or Hermitian constraints do not interfere with the Dempster property of the maximum entropy completion. I.e., regardless of which elements are specified, the completion has the Dempster property. This fact is a direct consequence of the invariance of the determinant to the group of transformations that leave circulant, block-circulant, or Hermitian matrices invariant. A description of the set of all positive extensions is discussed and connections between this set and the factorization of certain polynomials in many variables, facilitated by the circulant structure, is highlighted.**

## Codes and Rings
*(Invited Session)*

**Room 14**

***Organizers:*** *Joachim Rosenthal, Marcus Greferath*
***Chair:*** *Marcus Greferath*

10.30 – 11.00

On the Parameters of Two-Weight Codes over Rings
*Alfred Wassermann*

***Abstract*–Linear codes over rings are interesting because there are examples which can correct more errors than comparable linear codes over finite fields. Here, we look on the special case of linear codes attaining exactly two nonzero weights and give an exhaustive list on the weights of such codes.**

11.00 – 11.30

Predictable Degree Property and Row Reducedness for a System over a Semi Simple Ring
*Mohammed El Oued, Patrick Solé*

***Abstract*— We study a linear discrete time dynamical system $B$ on the finite ring $\mathbb{Z}_n$. A kernel representation theorem is derived. In the case of $n = p_1^{r_1} \ldots p_m^{r_m}$ we introduce the notions of $(p_1, \ldots, p_m)-$property for the predicted degree and of $(p_1, \ldots, p_m)-$regularity.**

11.30 – 12.00

A New Series of $Z_4$-Linear Codes of High Minimum Lee Distance Derived from the Kerdock Codes
*Michael Kiermaier, Johannes Zwanzger*

***Abstract*— A new series of $\mathbb{Z}_4$-linear codes of high minimum Lee distance is given. It is derived from the $\mathbb{Z}_4$-linear representation of the Kerdock codes. The Gray image of the smallest of these codes is a nonlinear binary $(114, 2^8, 56)$-code, and in the second smallest case the Gray image is a nonlinear binary $(1988, 2^{12}, 992)$-code. Both codes have at least twice as many codewords as any linear binary code of equal length and minimum distance.**

12.00 – 12.30

Constructions of Two-Weight Codes over Finite Rings
*Eimear Byrne, Alison Sneyd*

Delsarte ([6], [7]) showed that a projective code over $GF(q)$ with two non-zero Hamming weights yields a strongly regular graph. In [1] this result was extended to the case of a regular, projective code with two non-zero homogeneous weights over a finite Frobenius ring. Some constructions of two-weight codes over $GF(q)$ arise from taking unions of subspaces of $GF(q)^k$ (c.f. [4]). Here we describe some families of two-weight codes found using unions of submodules of $R_R^k$, where $R$ is a finite Frobenius ring. Although the resulting codes are neither regular nor projective, they determine strongly regular graphs that are isomorphic to graphs from orthogonal arrays. We also show that the elements of certain rings give rise to strongly regular graphs.

## Max-Plus, Tropical and Idempotent Methods in Control – 1

*(Invited Session)*

**Room 15**

***Organizers:*** *John S. Baras, William M. McEneaney*
***Chair:*** *John S. Baras*

10.30 – 11.00

Routing in Equilibrium
*João Luís Sobrinho, Timothy G. Griffin*

***Abstract*–Some path problems cannot be modeled using semirings because the associated algebraic structure is not distributive. Rather than attempting to compute globally optimal paths with such structures, it may be sufficient in some cases to find locally optimal paths-paths that represent a stable local equilibrium. For example, this is the type of routing system that has evolved to connect Internet Service Providers (ISPs) where link weights implement bilateral commercial relationships between them. Previous work has shown that routing equilibria can be computed for some non-distributive algebras using algorithms in the Bellman-Ford family. However, no polynomial time bound was known for such algorithms. In this paper, we show that routing equilibria can be computed using Dijkstra's algorithm for one class of non-distributive structures. This provides the first polynomial time algorithm for computing locally optimal solutions to path problems. We discuss possible applications to Internet routing.**

11.00 – 11.30

Stochastic Perturbations of Deterministic Optimization Problems with Applications to a Spin Control Problem (Control of a Two-Level Atom)
*Vassili N. Kolokoltsov*

*The main characteristics of a long-time optimal process are determined by the solutions $(\lambda, h)$ (where $\lambda$ is a number and h a function on the state space) of the equation $Bh = \lambda + h$, where B is the Bellman operator of the optimization problem. Namely, $\lambda$ is the mean income per step of the process, whereas h specifies stationary optimal strategies or even turnpike control modes. For deterministic control problems, in which B is linear in the sense of the operations $\oplus = \min$ or $\oplus = \max$ and $\odot = +$, this equation is the idempotent analog of an eigenvector equation in standard linear algebra. Lots of papers are devoted top its study, see e.g. [6], [7] and references therein. In the case of stochastic control, the Bellman operator is no longer linear in the idempotent semimodule in general. However, as we are going to show, developing the results from the author's paper [1] (see also [3] and [4], if the influence of stochastic factors is small, it can be considered as nearly linear and perturbation theory can be developed. This kind of small stochasticity arises in some models of control over quantum systems that are presently subject to intensive research. The study of this example uses the quantum stochastic filtering theory, see [5].*

11.30 – 12.00

Asymptotic Values of Zero Sum Repeated Games: Evolution Equations in Discrete and Continuous Time
*Guillaume Vigeral*

***Abstract*— We consider some discrete and continuous dynamics in a Banach space involving a non expansive operator $J$ and a corresponding family of strictly contracting operators $\Phi(\lambda, x) := \lambda J(\frac{1-\lambda}{\lambda}x)$ for $\lambda \in ]0,1]$. Our motivation comes from the study of two-player zero-sum repeated games, where the value of the $n$-stage game (resp. the value of the $\lambda$-discounted game) satisfies the relation $v_n = \Phi(\frac{1}{n}, v_{n-1})$ (resp. $v_\lambda = \Phi(\lambda, v_\lambda)$) where $J$ is the Shapley operator of the game. We study the evolution equation $u'(t) = J(u(t)) - u(t)$ as well as associated Eulerian schemes, establishing a new exponential formula and a Kobayashi-like inequality for such trajectories. We prove that the solution of the non-autonomous evolution equation $u'(t) = \Phi(\boldsymbol{\lambda}(t), u(t)) - u(t)$ has the same asymptotic behavior (even when it diverges) as the sequence $v_n$ (resp. as the family $v_\lambda$) when $\boldsymbol{\lambda}(t) = 1/t$ (resp. when $\boldsymbol{\lambda}(t)$ converges slowly enough to 0).**

12.00 – 12.30

Local Pruning for Information Dissemination in Dynamic Networks for Solving the Idempotent Semiring Algebraic Path Problem
*Kiran K. Somasundaram, John S. Baras*

***Abstract*–We present a method, inspired from routing in dynamic data networks, to solve the Semiring Algebraic Path Problem (SAPP) for dynamic graphs. The method can be used in dynamic networks such as Mobile Ad Hoc Networks, where the network link states are highly dynamic. The algorithm makes use of broadcasting as primary mechanism to recompute the SAPP solution. The solution suffers from broadcast storm problems, and we propose a selective broadcasting mechanism that reduces the broadcast storm. We call this method local pruning and prove its correctness.**

## Semiplenary Lecture

**Room 1**

***Chair:*** *László Gerencsér*

14.00 - 15.00

Variable Robustness Control: Principles and Algorithms
*Marco C. Campi, Simone Garatti*

***Abstract*–Robust control is grounded on the idea that a design should be guaranteed against all possible occurrences of the uncertain elements in the problem. When this philosophy is applied to securing a desired performance, it often leads to conservative, low performing, designs because emphasis is all placed on the worst-case situation. On the other hand, in many applications a 100%-guarantee is not necessary, and it may be convenient to opt for a small compromise in the**

guarantee level, say 99%, in favor of a (possibly significant) improvement in the performance. While the above reasoning sets a sensible principle, to date the real stumbling-block to its practical use is the lack of computationally-tractable algorithmic methods to trade guarantees for performance. This paper aims to open new directions to address this problem, and we show that this result can be achieved through randomization.

## Semiplenary Lecture

**Room 14**

***Chair:*** *Lars Grüne*

14.00 - 15.00

Synthesis of Electrical and Mechanical Networks
*Malcolm C. Smith*

***Abstract*–The synthesis of electrical networks whose driving-point immittance is some prescribed positive-real function has given rise to a rich classical theory including the celebrated results of Brune, Darlington, Bott and Duffin etc. After the 1970s, there was a decline in interest due to the increasing prevalence of active circuits. Despite the relative maturity of the field, some basic questions remained unanswered, e.g. on the most efficient realisations for transformerless synthesis. The latter question becomes important again in the context of mechanical networks with the introduction of the inerter as an ideal two-terminal analogue of the capacitor (in contrast to the mass element which is analogous only to the grounded capacitor). This talk will discuss the motivation for passive mechanical network synthesis, survey some classical results of electric circuit synthesis, and discuss recent progress on the concept of regular positive-real functions and its application to transformerless synthesis.**

## Semiplenary Lecture

**Room 15**

***Chair:*** *Uwe Helmke*

14.00 - 15.00

Quantify the Unstable
*Li Qiu*

***Abstract*–The Mahler measure, a notion often appearing in the number theory and dynamic system literature, provides a way to quantify the instability in a linear discrete-time system.**

## Distributed Parameter Systems II: System Theoretical Properties
*(Invited Session)*

**Room 1**

***Organizers:*** *Birgit Jacob, Michael A. Demetriou, Miroslav Krstic, Kirsten Morris, Hans Zwart*
***Chair:*** *Birgit Jacob*

15.30 – 16.00

Non-Dissipative Boundary Feedback for Elastic Beams
*Chris Guiver, Mark R. Opmeer*

***Abstract*–We show that a non-dissipative feedback that has been shown in the literature to exponentially stabilize an Euler- Bernoulli beam makes a Rayleigh beam and a Timoshenko beam unstable.**

16.00 – 16.30

Absolute Stability of a System with Distributed Delays Modeling Cell Dynamics in Leukemia
*Hitay Özbay, Houda Benjelloun, Catherine Bonnet, Jean Clairambault*

***Abstract*–In this paper we consider a mathematical model proposed recently by Adimy et al. (2008) for studying the cell dynamics in Acute Myelogenous Leukemia (AML). By using the circle and Popov criteria, we derive absolute stability conditions for this nonlinear system with distributed delays. Connections with the earlier results on stability of the linearized model are also made. The results are illustrated with a numerical example and simulations.**

16.30 – 17.00

Admissibilty for Volterra Systems with Scalar Kernels
*Bernhard H. Haak, Birgit Jacob*

***Abstract*–Volterra observations systems with scalar kernels are studied. New sufficient conditions for admissibility of observation operators are developed.**

17.00 – 17.30

Multiscale Dynamics Optimal Control of Parabolic PDE with Time Varying Spatial Domain (Crystal Growth Process)
*James Ng, Ilyasse Aksikas, Stevan Dubljevic*

***Abstract*–This paper considers the multi-scale optimal control of the Czochralski crystal growth process. The temperature distribution of the crystal is realized by heat input at the boundary and by the force applied to the mechanical subsystem drawing the crystal from a melt. A parabolic partial differential equation (PDE) model describing the temperature distribution of the crystal is developed from first-principles continuum mechanics to preserve the time-varying spatial domain dynamical features. The evolution of the temperature distribution is coupled to the pulling actuator finite-dimensional subsystem with dynamics modelled as a second order ordinary differential equation (ODE) for rigid body mechanics. The PDE timevarying spatial operator with natural boundary conditions is characterized as a Riesz-spectral operator in the $L_2(0; l(t))$ functional space setting. The finite and infinite-time horizon optimal control law for the infinite-dimensional system is obtained as a solution to a time-dependent and time-invariant differential Riccati equation.**

## 2. System Identification
*(Regular Session)*

**Room 2**

***Chair:*** *Ignat Domanov*

15.30 – 16.00

Enhanced Line Search for Blind Channel Identification Based on the Parafac Decomposition of Cumulant Tensors
*Ignat Domanov, Lieven de Lathauwer*

***Abstract*–In this paper we consider higher-order cumulant based methods for the blind estimation of a single-input single-output finite impulse response system driven by a non- Gaussian signal. This problem can be interpreted as a particular polynomial optimization problem. Using the link between this problem and the parallel factor decomposition of a third-order tensor we present a new representation of the cost function and give an explicit expression for its complex gradient. Then we explore convergence/non convergence of the single-step leastsquares algorithm and improve it by enhanced line/plane search procedures.**

16.00 – 16.30

Quantification of Model Uncertainty for a State-Space System

*Wafa Farah, Guillaume Mercère, Thierry Poinot, Jan-Willem van Wingerden*

***Abstract*–In this communication, the uncertainty domain determination problem for multi-input multi-output systems described with a linear time-invariant state-space representation is adressed. The developed method is based on a two-step approach. The first step consists in estimating the nominal model using a particular least-squares subspace algorithm. Then, the uncertainty domains are described by using a bounded error approach. Simulations are used to highlight the performance of the method.**

16.30 – 17.00

On Asymptotic Properties of MOESP-Type Closed-Loop Subspace Model Identification

*Hiroshi Oku*

***Abstract*–Recently, MOESP-type closed-loop subspace model identification (CL-MOESP) has been proposed by the authors and its effectiveness has been demonstrated via both numerical simulations and real-life systems, e.g., a cart-inverted pendulum system. However, asymptotic properties of CLMOESP has not yet been studied. The purpose of this paper is to clarify the asymptotic properties of CL-MOESP from the viewpoint of Two-stage closed-loop identification. Moreover, it is shown that CL-MOESP minimizes a truncation error due to a finite number of sampled data.**

17.00 – 17.30

Regularized Parametric Models of Nonstationary Processes

*Daniel Rudoy, Tryphon T. Georgiou*

***Abstract*–In this article, we study two classes of nonstationary processes respectively parameterized by time-varying autoregressions and time-varying lattice filters. The processes considered are induced by solutions to certain convex optimization problems with local or global constraints, and are consistent with standard models of their stationary counterparts. We show that an underlying nesting property naturally leads to a family of hypothesis tests for stationarity and provide a geometric interpretation of our results on the manifold of allpole rational transfer functions.**

17.30 – 18.00

Coupled Segmentation for Anatomical Structures by Combining Shape and Relational Spatial Information

*Ivan Kolesov, Vandana Mohan, Gregory Sharp, Allen R. Tannenbaum*

***Abstract*–We propose a sequential method to estimate a shape prior using previously segmented structures as landmarks. It is founded on probabilistic principal component analysis and probabilistic canonical correlation analysis. We derive equations in order to utilize these techniques for prediction. At a given stage in a sequence of segmentations, this approach predicts the most likely shape of the structure being segmented based solely on the segmentations of completed structures. Hence, the shape prior is independent of the image information around the target. This is applied to the problem of adaptive radiotherapy in oncology. Structures of interest in the head and neck region have insufficient image information and strictly image based approaches fail. Such cases also present major problems for methods that simultaneously perform segmentation and fitting of a shape model to image data. The strength of our method is the flexibility that it provides to the user in determining what image information to trust. We demonstrate our technique on a dataset that is illustrative of real-world data for our applications in volume and in variance.**

## Structural Properties of Realizations

*(Regular Session)*

**Room 3**

***Chair:*** *W. Steven Gray*

15.30 – 16.00

On the Rationality of the Feedback Connection

*W. Steven Gray*

***Abstract*–This paper presents a variety of necessary conditions and sufficient conditions under which the feedback interconnection of two rational input-output systems, that is, systems having bilinear state space realizations, produces a closed-loop system which is also rational.**

16.00 – 16.30

On the Existence of Various Realizations

*Jana Němcová, Jean-Baptiste Pomet*

***Abstract*–The aim of this paper is to characterize the existence of polynomial, rational and Nash realizations with respect to one another. The existence of realizations within various classes of systems is the main topic of realization theory. In this paper it is shown that if there exists a polynomial realization of a response map then there exists also its rational realization. To disprove the converse implication we provide an example of a response map which is realizable by a rational system but not by a polynomial system. Further, it is shown that the existence of a rational realization implies the existence of a Nash realization of the same response map. The equivalence is proven for response maps defined on piecewise-constant inputs the values of which are of a finite set. However, the question whether the existence of a Nash realization implies the existence of a rational realization generally is still open. Additionally, we discuss the observability properties of polynomial, rational and Nash systems.**

16.30 – 17.00

External Dynamical Equivalence of Time-Varying Nonlinear Control Systems on Time Scales

*Zbigniew Bartosiewicz, Ewa Pawłuszewicz*

***Abstract*–Theory of systems on homogeneous time scales unifies theories of continuous-time and discrete-time systems. The characterizations of external dynamical equivalence known for continuous-time and discrete-time systems with outputs are extended to time-varying systems on time scales. The main result says that two nonlinear control systems are externally weakly dynamically equivalent if and only if their delta universes are properly isomorphic. The delta operator associated to the given system on a time scale is a generalization of the differential operator associated to a continuous-time system and of the difference operator associated to a discrete-time system.**

17.00 – 17.30

Spaces of Nonlinear and Hybrid Systems Representable by Recognizable Formal Power Series

*Mihály Petreczky, Ralf Peeters*

***Abstract*–The paper presents the manifold structure of the spaces of those nonlinear and hybrid system which can be encoded by rational formal power series. The latter class contains bilinear systems, linear multidimensional systems, linear switched and hybrid systems and jump-markov linear systems.**

## New Mathematical Methods in Multidimensional Systems Theory – 2

*(Invited Session)*

**Room 4**

***Organizers:*** *Alban Quadrat, Thomas Cluzeau*
***Chair:*** *Thomas Cluzeau*

15.30 – 16.00

Frobenius Method for Computing Power Series Solutions of Linear Higher-Order Differential Systems
*Moulay Barkatou, Thomas Cluzeau, Carole El Bacha*

***Abstract*–Linear matrix differential systems appear in many fields of mathematics and many applications in mathematical physics and control theory. Computing power series solutions of such systems around singularities can help in the understanding of the underlying problem.**

**The first goal of the present paper is to give a survey on the classical Frobenius method for computing power series solutions of linear scalar differential equations. Then the first contribution of the paper is to show how this Frobenius method can be generalized to handle general linear higher-order differential systems.The last part of the paper is dedicated to the study of higher-order matrix differential control systems for which we show how to use such a technique to compute power series solutions.**

16.00 – 16.30

Controllability and Differential Flatness of Linear Analytic Ordinary Differential Systems
*Alban Quadrat, Daniel Robertz*

***Abstract*–Based on an extension of Stafford's classical theorem in noncommutative algebra [24] obtained in [4], the purpose of this paper is to show that every controllable linear ordinary differential system with convergent power series coefficients (i.e., germs of real analytic functions) and at least two inputs is differentially flat. This result extends a result obtained in [20], [21] for linear ordinary differential systems with polynomial coefficients. We show how the algorithm developed in [21] for the computation of injective parametrizations and bases of free differential modules with polynomial or rational function coefficients can be used to compute injective parametrizations and flat outputs for these classes of differentially flat systems. This algorithm allows us to remove singularities which naturally appear in the computation of injective parametrizations and bases obtained by means of Jacobson normal form computations.**

16.30 – 17.00

Extendability of Multidimensional Linear Systems
*Alban Quadrat*

***Abstract*–Within the algebraic analysis approach to multidimensional linear systems defined by linear systems of partial differential equations with constant coefficients, the purpose of this paper is to show how to use different mathematical results developed in the literature of algebraic analysis to obtain new characterizations of the concepts of controllability, in the sense of Willems and Pillai-Shankar, observability, flatness and autonomous systems in terms of the possibility to extend (smooth or distribution) solutions of the multidimensional system and of its formal adjoint. Each characterization is equivalent to a moduletheoretic property that can be constructively checked by means of the packages OreModules and QuillenSuslin.**

17.00 – 17.30

Module Structure of Classical Multidimensional Systems Appearing in Mathematical Physics
*Thomas Cluzeau, Alban Quadrat*

***Abstract*–In this paper, within the constructive algebraic analysis approach to linear systems, we study classical linear systems of partial differential (PD) equations in two or three independent variables with constant coefficients appearing in mathematical physics and engineering sciences such as the Stokes and Oseen equations studied in hydrodynamics. We first provide a precise algebraic description of the endomorphism ring of the left *D*-module associated with a linear PD system. Then, we use it to prove that the endomorphism ring of the Stokes and Oseen equations in $\mathbf{R}^2$ is a cyclic *D*-module, which allows us to conclude about the decomposition and factorization properties of these linear PD systems.**

## Noncommutative Rational Functions and Noncommutative Convexity – 2

*(Mini-Course)*

**Room 6**

***Organizers:*** *William J. Helton, Dmitry S. Kaliuzhnyi-Verbovetskyi, Igor Klep, Victor Vinnikov*

15.30 – 17.30

Noncommutative Rational Functions and Noncommutative Convexity
*William J. Helton, Dmitry S. Kaliuzhnyi-Verbovetskyi, Igor Klep, Victor Vinnikov*

## Networked Systems *(Regular Session)*

**Room 7**

***Chair:*** *Thomas E. Gorochowski*

15.30 – 16.00

A Dynamical Approach to the Evolution of Complex Networks
*Thomas E. Gorochowski, Mario di Bernardo, Claire S. Grierson*

***Abstract*–In this work we take a dynamical approach to the evolution of complex networks using simulated output of the full system dynamic to direct evolution of the underlying network structure. Extending previous work, we study the problem of enhanced synchronisation and the generality of Type 2 features which have been shown to emerge in regimes where full synchronisation is unstable. Networks are evolved using a new computational tool called NetEvo which aims to minimise a dynamical order parameter performance measure. This process is performed for networks with several alternative node dynamics, showing in all cases that qualitatively similar Type 2 topologies emerge. Analysis of these structures highlights variation in many of the network statistics and motif frequencies, but helps to classify some key characteristics exhibited by all Type 2 networks, regardless of node dynamic.**

16.00 – 16.30

Betweenness Centrality Dynamics in Networks of Changing Density
*László Gulyás, Gábor Horváth, Tamás Cséri, Zalán Szakolczy, George Kampis*

***Abstract*–Dynamic networks are recently in the foreground of interest in various fields that deal with complex systems, such as sociology and biology (especially ecology and**

systems biology and epidemiology). Betweenness centrality of nodes is a particularly valued concept as a tool for characterizing large networks by way of selected nodes. In the present study, we were interested in the effects of various network changes on average betweenness (BW) centrality in networks of changing densities. We applied two different treatments in 100 trials on classic random networks models. In treatment one, we created various instances of the studied network models with different densities. We used classic network model families such as Erdős-Rényi (ER), Barabási-Albert (BA) models, among others, and compared these with empirical network data at various densities. In treatment two, we studied the robustness of networks by simulating random node failures and planned attacks according to two scenarios.

16.30 – 17.00

Motion Programs for Multi-Agent Control: From Specification to Execution
*Patrick Martin, Magnus Egerstedt*

*Abstract*–This paper explores the process of turning highlevel motion programs into executable control code for multiagent systems. Specifically, we use a modified Motion Description Language (MDL) for networked systems that can specify motion programs for a collection of autonomous agents. This MDL includes the network information dependencies required for each agent to perform coordinated behaviors. We discuss the design of this framework and the language theoretic tools used to analyze the information dependencies specified by these multi-agent motion programs. Additionally, we develop a supervisor system that monitors the behavior of the agents on the network, and prevents the agents from entering into states where information dependencies are violated. We demonstrate our framework using a simulated multi-robot system.

17.00 – 17.30

Minimal-time Uncertain Output Final Value of Unknown DT-LTI Systems with Application to the Decentralised Network Consensus Problem
*Ye Yuan, Guy-Bart Stan, Ling Shi, Mauricio Barahona, Jorge Gonçalves*

*Abstract*–For an unknown discrete-time linear timeinvariant (DTLTI) autonomous system, this paper characterises the minimal number of steps necessary to compute the asymptotic final value of an output observed with uncertainty. We show that this minimal number of steps can also be obtained directly from a graphical representation of the DTLTI system using Mason's rule. Moreover, we provide heuristic algorithms to compute the final value in a minimal amount of time with uncertain observations. The general structure of these algorithms is as follows. Step one, by introducing a one-step prediction error metric, we characterise the minimal length of recursion for the outputs of the considered DTLTI system. Step two, by constructing a new data set "close" to the original uncertain output data set satisfying certain conditions, we estimate the final value of the original output set by computing the final value associated with this new data set. Step three, we characterise the difference between the estimated final values obtained from different estimated data sets. Furthermore, we also consider systems with time-delays and investigate how the delays affect the minimal number of steps required to compute the final value. These results find applications in minimal-time network consensus problems with minimal and uncertain (e.g., noisy) information.

## Observer Theory
*(Invited Session)*

**Room 8**

***Organizer:*** *Jochen Trumpf*
***Chair:*** *Jochen Trumpf*

15.30 – 16.00

Functional *T*-Observers
*Ingrid Blumthaler*

*Abstract*— Observer theory in the behavioral context has been started by M. E. Valcher and J. C. Willems in 1999 and was recently exposed by P. Fuhrmann in a comprehensive survey article. In our setting, we consider a (continuous or discrete time) linear behavior $\mathcal{B}$ and assume that we have access to the linear image $P \circ w$ of a trajectory $w \in \mathcal{B}$. Our goal is the construction of an input/output behavior $\mathcal{B}_{\text{obs}}$ that accepts $P \circ w$ as input and outputs an estimation of another linear image $Q \circ w$. We define resp. generalize the terms $T$-*observability* and $T$-*observer* where $T$ denotes a multiplicatively closed set of non-zero operators. For different choices of $T$, $T$-observability coincides with observability, reconstructibility, trackability, or detectability, a $T$-observer is an exact, dead-beat, tracking, or asymptotic observer. We characterize $T$-observability, show that it is equivalent to the existence of $T$-observers, and constructively parametrize all $T$-observers for a given behavior $\mathcal{B}$ and linear maps $P$ and $Q$. Corresponding results for *proper* $T$-observers are also obtained.

Our framework includes as special case partial observation of the state of a Kalman state space system (compare e.g. Luenberger's state observers or Fuhrmann's work), as well as observers of certain unknown components of a behavior as studied by Bisiacco, Valcher, and Willems. Also functional observers in context with Rosenbrock equations or polynomial matrix descriptions, compare Wolovich's work from 1974, are included in our theory.

The results stated above are derived by means of a new technique developed by Oberst involving the localization of the ring of operators with respect to the set $T$ and the localization of the injective cogenerator signal module with respect to $T$. The fact that the latter is an injective cogenerator over the former is central. This technique allows very short, elegant and conceptual proofs.

All mentioned results have been published in *Functional T-observers*, Linear Algebra and its applications, 432:1560–1577, 2010.

16.00 – 16.30

$H_\infty$ Observers Design for a Class of Continuous Nonlinear Singular Systems
*Mohamed Darouach, Latifa Boutat-Baddas, Mohamed Zerrougui*

*Abstract*–This paper presents a new solution to the $H_\infty$ observers design problem for a class of Lipschitz continuous nonlinear singular systems. The approach is based on the parameterization of the solution of generalized Sylvester equations. Sufficient conditions for the existence of the observers which guarantee stability and the worst case observers error energy over all bounded energy disturbances is minimized are given. The method also concerns the full-order, reduced-order, minimal-order observers design A numerical example is given to show the applicability of our results.

16.30 – 17.00

Observability of Partial States of Invariant Systems
*Christian Lageman*

*Abstract*–This paper considers the observability of partial states of an invariant control system on a Lie group. Specifically we consider in this paper left invariant systems where the outputs and the partial states are given by actions of

**the group on different manifolds. Depending of the type of these actions we give characterizations of partial state observability and for some cases additional sufficient observability criteria.**

17.00 – 17.30

Error Models for Nonlinear Observers
*Jochen Trumpf, Robert Mahony, Stefano Stramigioli*

***Abstract*–We revisit the concept of observation error for nonlinear observers of nonlinear systems. In order to obtain a coordinate free notion of such an error we define it using fiber bundles over the system manifold. The new notion ties in nicely with Brockett's and Willems' classical description of nonlinear systems as bundles as well as with the related description of observers as bundles due to van der Schaft. It identifies the nonlinear observer design problem as the problem of choosing a nonlinear connection form (horizontal distribution plus affine offset) in this bundle with certain desirable properties. We demonstrate how a particular solution to this connection design problem is given by the invariant observers of Bonnabel, Martin and Rouchon. In the case of systems on Lie groups we recover the recent results by Lageman and two of the authors.**

## Sampled Control
*(Regular Session)*

**Room 9**

***Chair:*** *Emilia Fridman*

15.30 – 16.00

Sampled-Data Stabilization of a Class of Parabolic Systems
*Emilia Fridman, Anatoly Blighovsky*

***Abstract*–A semilinear scalar heat equation with the control input in the right-hand side, coupled to the homogenous Dirichlet or Neumann boundary conditions, is considered. Such a system represents a class of reaction-diffusion equations that model many physical phenomena. It is well-known that this system is stabilizable by a linear infinite-dimensional state-feedback. For realistic design, finite-dimensional discrete version realizations may be applied leading to local results. In the present paper we suggest a sampled-data controller design, where the sampled-data (in time) measurements of the state are taken in the finite number of fixed (sampled) spatial variables. It is assumed that the sampling in time and the sampling in space (i.e. the distance between the consequently sampled spatial variables) are bounded. Our sampled-data feedback with a constant gain is piecewise-constant in time and in space. Sufficient conditions for the exponential stabilization are derived in terms of Linear Matrix Inequalities (LMIs) depending on the controller gain. By solving these LMIs, upper bounds on the sampling in time and on the sampling in space are found that preserve the exponential stability. The results are extended to the sampled-data in space and to delayed in time sampled-data measurements. A numerical example illustrates the efficiency of the method.**

16.00 – 16.30

Truncated Norms and Limitations on Signal Reconstruction
*Gjerrit Meinsma, Hanumant Singh Shekhawat*

***Abstract*–Design of optimal signal reconstructors over all samplers and holds boils down to canceling frequency bands from a given frequency response. This paper discusses limits of performance of such samplers and holds and develops methods to compute the optimal $L^2$-norm.**

16.30 – 17.00

On the Consistency of $L^2$-Optimal Sampled Signal Reconstructors
*Gjerrit Meinsma, Leonid Mirkin*

***Abstract*–The problem of restoring an analog signal from its sampled measurements is called the signal reconstruction problem. A reconstructor is said to be consistent if the resampling of the reconstructed signal by the acquisition system would produce exactly the same measurements. The consistency requirement is frequently used in signal processing applications as the design criterion for signal reconstruction. System-theoretic reconstruction, in which the analog reconstruction error is minimized, is a promising alternative to consistency-based approaches. The primary objective of this paper is to investigate, what are conditions under which consistency might be a byproduct of the system-theoretic design that uses the $L^2$ criterion. By analyzing the $L^2$ reconstruction in the lifted frequency domain, we show that non-causal solutions are always consistent. When causality constraints are imposed, the situation is more complicated. We prove that optimal relaxedly causal reconstructors are consistent either if the acquisition device is a zero-order generalized sampler or if the measured signal is the ideally sampled state vector of the antialiasing filter. In other cases consistency can no longer be guaranteed as we demonstrate by a numerical example.**

17.00 – 17.30

Stability Analysis of Aperiodic Sampled-Data Control Systems: an Improved Approach Using Matrix Uncertainty
*Yasuaki Oishi, Hisaya Fujioka*

***Abstract*–Stability analysis is considered on a sampled-data control system with an uncertain/time-varying sampling interval. A stability condition is given in a linear matrix inequality, readily tested with the interior-point method. Conservatism of the condition can be reduced to any degree by dividing the region of the possible sampling intervals. Reduction of the computational complexity as well as generalization to design of a state-feedback gain is considered. This approach is a simplification of the previous approach of the same authors and does not need the real Jordan canonical form, which is difficult to compute for a large-sized matrix.**

## Algebraic Structures – 2 *(Regular Session)*

**Room 10**

***Chair:*** *Kenji Fujimoto*

15.30 – 16.00

Variational Symmetry of Discrete-Time Hamiltonian Systems and Learning Optimal Control
*Kenji Fujimoto, Soraki Ogawa*

***Abstract*–Variational symmetry is a property of Hamiltonian control systems. It is the basis for learning optimal control. In order to apply a continuous-time control strategy to a real plant, we need to discretize the data with respect to time. This paper investigates the variational symmetry for the discretized Hamiltonian systems. It is proved that the discretization based on the midpoint rule preserves the variational symmetry of the original system. Furthermore, a learning optimal control method based on the midpoint rule is proposed.**

16.00 – 16.30

Reproducing Kernels Preserving Algebraic Structure: a Duality Approach

*Tzvetan Ivanov, Balázs Csanád Csáji*

***Abstract*–From the classical reproducing kernel theory of function spaces it is well-known that there is an inverse relationship between inner-products and kernels. In applications, such as linear system theory and machine learning, these kernels are often highly structured. In order to exploit algebraic structure, it is common to choose basis functions and fall back to matrix representations. However, the basis has to be chosen in a way that is compatible with the algebraic structure, which is itself a nontrivial task. We therefore choose a different approach and use standard duality theory where additional algebraic structures form no obstacle. This is demonstrated by examples from linear system theory, namely two variable polynomials given by Bézoutians and quadratic differential forms.**

16.30 – 17.00

A Spinor Approach to Port-Hamiltonian Systems

*Johannes G. Maks*

***Abstract*–The key concept in the implicit definition of a port-Hamiltonian system is the geometric notion of a Dirac structure. A Dirac structure is a maximal isotropic subspace of the direct sum of the vector space of flows and its dual space of efforts. There exist several ways to represent a Dirac structure. One approach that appears to be unknown to the systems and control community is the pure spinor approach based on the work of É. Cartan. It is the purpose of this paper to explain the spinor formalism and to show how a port-Hamiltonian system is reformulated in the language of spinors.**

17.00 – 17.30

On Computing Normalized Coprime Factorizations of Periodic Systems

*András Varga*

***Abstract*–A numerically reliable state space algorithm is proposed for computing normalized coprime factorizations of periodic descriptor systems. A preprocessing step is used in the algorithm to convert the initial problem for possibly non-causal systems into a simpler problem for causal periodic systems. The main computational ingredient here is the computation of a coprime factorization with causal factors which is addressed by computing right annihilators of an appropriately extended system via periodic pencil manipulation algorithms. The solution of the normalized coprime factorization problem for a causal system involves the solution of a generalized periodic Riccati equation. The proposed two steps approach is completely general, being applicable to periodic systems with time-varying dimensions.**

## Delay Systems

*(Regular Session)*

**Room 11**

***Chair:*** *Lars Naujok*

15.30 – 16.00

Lyapunov-Razumikhin and Lyapunov-Krasovskii Theorems for Interconnected ISS Time-Delay Systems

*Sergey Dashkovskiy, Lars Naujok*

***Abstract*–We consider an arbitrary number of interconnected nonlinear systems with time-delays and investigate them in view of input-to-state stability (ISS). The useful tools for single time-delay systems, the ISS Lyapunov-Razumikhin functions and ISS Lyapunov-Krasovskii functionals are redefined and applied to interconnected systems. By the help of a smallgain condition we prove that the whole system with time-delays has the ISS property, if each subsystem has an ISS Lyapunov- Razumikhin function or ISS Lyapunov-Krasovskii functional. Furthermore we construct the ISS Lyapunov-Razumikhin (- Krasovskii) function(al) and the corresponding gains of the whole system.**

16.00 – 16.30

Monodromy Operator Approach to Time-Delay Systems: Fast-Lifting Based Treatment of Operator Lyapunov Inequalities

*Tomomichi Hagiwara*

***Abstract*–This paper establishes a new fundamental framework of an operator-theoretic approach to linear time-invariant (LTI) time-delay systems (TDSs). The state transition of TDSs is first viewed in discrete-time and described by a bounded operator called the monodromy operator. A stability condition in terms of the spectral radius of the monodromy operator is given, which in turn is related to an operator Lyapunov inequality about that operator. A special class of operators, parametrized by two finite-dimensional (FD) constant matrices and constructed via the fast-lifting technique, is then introduced, which is ensured to contain a nonempty subset of the solutions to the operator Lyapunov inequality whenever the TDS is stable and the fast-lifting parameter *N* is large enough. A fundamental framework for asymptotically exact stability analysis is thus established. An equivalent scaling treatment is also shown, and further generalization of the arguments is carried out with the use of Legendre polynomials in the construction of the above operator class. These arguments proceed in a rather linear algebraic way with many similarities to the stability analysis of FDLTI discrete-time systems. The presented framework could be said to be a "pseudo-discretization" technique; it allows one to essentially reduce the arguments on infinite-dimensional operators to those about two matrices, with an increasing degree of freedom as *N* gets larger, but without introducing any matrix approximation of infinite-dimensional operators.**

16.30 – 17.00

Monodromy Operator Approach to Time-Delay Systems: Numerical Method for Solving Operator Lyapunov Inequalities

*Tomomichi Hagiwara, Takayuki Inui*

***Abstract*–This paper extends the technique for stability analysis of time-delay systems based on the operator Lyapunov inequalities about (fast-lifted) monodromy operators by establishing a numerical method for solving the operator Lyapunov inequalities. First, quasi-finite-rank approximation is applied to the fast-lifted monodromy operator, and an operator Lyapunov inequality is considered with respect to the resulting approximated operator. Then, a numerically tractable method is developed for finding a solution to the approximated operator Lyapunov inequality out of a special class of operators that is known to be nonconservative (with respect to the original operator Lyapunov inequality before quasi-finite-rank approximation) as long as the fast-lifting parameter N is large enough. The above special class is described by two finitedimensional matrices, and thus solving the operator Lyapunov inequality amounts to solving a finite-dimensional LMI. In particular, due to the discrete-time viewpoint intrinsic to the (fast-lifted) monodromy operator approach, the resulting LMI is a discrete-time one, which is suitable for extension to the case with discrete-time controllers. A method is also provided to confirm that the solution to the approximated operator Lyapunov inequality does solve the original operator Lyapunov inequality. Furthermore, it is shown that the overall procedure gives an asymptotically exact numerical method for**

stability analysis of time-delay systems. A numerical example illustrating the arguments of the paper is also given. A brief sketch is also provided on the extension to the use of generalized hold and sampling operators $J_{Hk}$ and $J_{Sk}$ based on Legendre polynomials.

17.00 – 17.30

Well-Posedness of Problems Involving Time-Varying Delays
*Erik I. Verriest*

*Abstract*— Problems in defining state, state space, trajectory and stability for systems with time varying delays are expounded. First, it is shown that the information structure, providing the necessary side information, usually understood, but never made explicit, plays a significant role. It is then shown that when the delay derivative satisfies $\dot{\tau} < 1$, state space and hence stability are well defined. In the absence of this constraint, causality of the model may fail depending on the information structure. It is shown that embedding the delay in a larger fixed delay interval is also not always satisfactory, creating problems with consistency, minimality and well-posedness. Two causalizations are proposed which are useful within different information structures: lossless causalization for complete (omniscient) information and forgetful causalization if the delay is not predictable. Next, we consider the practically relevant problem (for networked control) when the delay is piecewise constant, and relate this to the recently introduced multi-mode multi-dimensional ($M^3D$) systems. Finally, we observe that in the discrete case, this $M^3D$ model is viable.

## Basic and Recent Results on Quantized Control
*(Invited Session)*

**Room 12**

***Organizers:*** *Toshiharu Sugie, Shun-ichi Azuma*
***Chair:*** *Toshiharu Sugie*

15.30 – 16.00

Coarseness in Quantization for Stabilization of Linear Systems over Networks
*Hideaki Ishii, Koji Tsumura, Tomohisa Hayakawa*

*Abstract*–We present an overview on the quantized control approach that was initiated by Elia and Mitter in the context of networked control. In particular, two recent extensions are presented where uncertainties in the channel and the plant are taken into consideration. The general problem setting is that the amount of communication is measured by a notion of coarseness in quantization, and we would like to find the coarsest quantizer for achieving stabilization. Numerical examples are provided to illustrate the differences among the quantized control schemes.

16.00 – 16.30

Stabilising Stochastic Linear Plants via Erroneous Channels
*Girish N. Nair, Kartik Venkat*

*Abstract*–In the field of networked control, a powerful methodology for constructing quantised controllers with rigorous stability bounds is the zooming strategy. This approach is attractive for implementation purposes since it yields finitedimensional schemes. However, most available results somewhat unrealistically require no transmission errors to occur in the channel. In this paper, a novel zooming-like scheme is proposed for controlling a stochastic linear plant over an erroneous digital channel, with neither transmitter nor receiver informed when errors occur. Using a stochastic pseudo-norm technique, it is shown that mean square stability can be achieved, provided that the number of quantisation points is sufficiently larger than the plant dynamical constant and the probability of symbol error is sufficiently small.

16.30 – 17.00

Introduction on Bit Memory Systems: approximation and Stabilization
*Koji Tsumura*

*Abstract*–In this paper, we introduce recent results on bit memory systems. The bit memory systems are operators from analog inputs to discretized outputs and their memories are elements of discrete numbers. Their dynamics is represented by the time evolution of the bit memories and output equations. In this paper, we consider an approximation problem or a stabilization problem of ordinary linear time invariant systems by the bit memory systems. Then, we consider the minimization problem of the bit length of the memories with which the bit memory systems attain a given error bound for the approximation problem or the stability of the closed loop systems for the stabilization problem. We show several upper and lower bounds of the bit length of memories in both of the problems.

17.00 – 17.30

Global Optimal Control of Quantized Systems
*Lars Grüne, Florian Müller*

*Abstract*–We propose a set oriented approach to the global infinite horizon optimal control of nonlinear systems with quantized state measurement and quantized control values. The algorithm relies on a dynamic programming principle in which the quantization error is modelled as an opponent in a min-max dynamic game formulation. For the solution of the problem we propose a set oriented approach followed by a graph theoretic optimization algorithm. We also discuss a dynamic feedback extension and illustrate the performance of the proposed approach by experimental results.

## Control of Distributed Stochastic Systems
*(Invited Session)*

**Room 13**

***Organizers:*** *Jan H. van Schuppen, Charalambos D. Charalambous*
***Chair:*** *Jan H. van Schuppen*

15.30 – 16.00

Decentralized Detection with Signaling
*Ashutosh Nayyar, Demosthenis Teneketzis*

*Abstract*–We consider a sequential problem in decentralized detection. Two observers can make repeated noisy observations of a binary hypothesis on the state of the environment. At any time, any of the two observers can stop and send a final message to the other observer or it may continue to take more measurements. After an observer has sent its final message, it stops operating. The other observer is then faced with a different stopping problem. At each time instant, it can decide either to stop and declare a final decision on the hypothesis or take another measurement. At each time, the system incurs an operating cost depending on the number of observers that are active at that time. A terminal cost that measures the accuracy of the final decision is incurred at the end. We show that, unlike in other sequential detection problems, stopping rules characterized by two thresholds on an observer's posterior belief no longer guarantee optimality in this problem. Thus the potential for signaling among observers alters the nature of optimal policies. We obtain a new parametric characterization of optimal policies for this problem.

16.00 – 16.30

Performance Evaluation of Multi-Agent Distributed Collaborative Optimization under Random Communication Topologies
*Ion Matei, John S. Baras*

***Abstract*–We investigate collaborative optimization in a multi-agent setting, when the agents execute in a distributed manner using local information, while the communication topology used to exchange messages and information is modeled by a graph-valued random process, independent of other time instances. Specifically, we study the performance of the consensus-based multi-agent subgradient method, for the case of a constant stepsize, as measured by two metrics: rate of convergence and guaranteed region of convergence, evaluated via their expected values. Under a strong convexity type of assumption, we provide upper bounds on the performance metrics, which explicitly depend on the probability distribution of the random graph and on the agents' estimates of the optimal solution. This provides a guide for tuning the parameters of the communication protocol such that good performance of the multi-agent subgradient method is ensured.**

16.30 – 17.00

On the Optimal Reconstruction Kernel of Causal Rate Distortion Function
*Charalambos D. Charalambous, Christos K. Kourtellaris, Photios A. Stavrou*

***Abstract*–This paper considers source coding of general sources with memory, when causal feedback is available at the decoder. The rate distortion function defined as the infimum of the directed information between source and reconstruction sequences over causal data compression channels, which satisfy a distortion fidelity constraint. The form of the optimal causal data compression Kernel is derived.**

17.00 – 17.30

Control of the Observation Matrix for Control Purposes
*René K. Boel, Jan H. van Schuppen*

***Abstract*–How to control the activiation of an expensive observation channel of a stochastic system? The control objective is to reduce the conditional error variance of state estimation but a cost is to be paid for acquiring a reading of the channel. The optimal control law depends only on the conditional error variance and has to be determined computationally. A second problem is to use the state estimate for control of the conditional mean. The solution method is stochastic control with partial observations.**

## Crypto and Applications
*(Invited Session)*

**Room 14**

***Organizers:*** *Joachim Rosenthal, Marcus Greferath*
***Chair:*** *Marcus Greferath*

15.30 – 16.00

Problems Related to Combinatorial Configurations with Applications to P2P-User Private Information Retrieval
*Maria Bras-Amorós, Klara Stokes, Marcus Greferath*

***Abstract*–We explain the applications that combinatorial configurations have to peer-to-peer user-private information retrieval and we analyze some problems that arise from these applications. In particular we deal with the existence of combinatorial configurations, the characterization of optimal configurations for peer-to-peer user-private information retrieval and the existence of configurations preventing collusion attacks of dishonest users.**

16.00 – 16.30

On Binary Sequences Generated by Self-Clock Controlled LFSR
*Michele Elia, Guglielmo Morgari, Maria Spicciola*

***Abstract*–The paper considers some peculiar properties of binary sequences generated by self-clocked linear feedback shift registers of maximum length, and compares these properties with those of truly random sequences. In particular it examines their periods, their 0-1 distributions, and their linear complexity profiles.**

16.30 – 17.00

On the Number of Linear Feedback Shift Registers with a Special Structure
*Srinivasan Krishnaswamy, Harish K. Pillai*

***Abstract*–Given a linear recurring relation whose characteristic polynomial is primitive, we find out the number of possible realisations using Linear Feedback Shift Registers (LFSRs) with 2-input 2-output delay elements. We show the equivalence between each realisation and a matrix having a special structure. Further, the number of realisations is computed by calculating the number of these structured matrices.**

17.00 – 17.30

Codes as Ideals over Some Pointed Hopf Algebras
*Juan Cuadra, Jose M. García-Rubira, Juan A. López-Ramos*

***Abstract*–We give a Decomposition Theorem for a family of Hopf algebras containing the well-know family of Taft Hopf algebras. Therefore, those indecomposable codes over this family of algebras (cf. [4]) is an indecomposable code over the studied case. We use properties of Hopf algebras to show that dual (in the module sense) of an ideal code is again an ideal code.**

## Max-Plus, Tropical and Idempotent Methods in Control – 2
*(Invited Session)*

**Room 15**

***Organizers:*** *John S. Baras, William M. McEneaney*
***Chair:*** *William M. McEneaney*

15.30 – 16.00

The Correspondence between Tropical Convexity and Mean Payoff Games
*Marianne Akian, Stéphane Gaubert, Alexander Guterman*

***Abstract*–We show that several decision problems originating from max-plus or tropical convexity are equivalent to zero-sum, two player game problems. In particular, we set up an equivalence between the external representation of tropical convex sets and zero-sum stochastic games, in which tropical polyhedra correspond to deterministic games with finite action spaces. Then, we show that the winning initial positions can be determined from the associated tropical polyhedron. We obtain as a corollary a game theoretical proof of the fact that the tropical rank of a matrix, defined as the maximal size of a submatrix for which the optimal assignment problem has a unique solution, coincides with the maximal number of rows (or columns) of the matrix which are linearly independent in the tropical sense. Our proofs rely on techniques from non-linear Perron-Frobenius theory.**

16.00 – 16.30

A Max-Plus Approach to the Approximation of Transient Bounds for Systems with Nonlinear $L_2$-Gain

*Huan Zhang, Peter M. Dower*

***Abstract*— The notion of nonlinear $\mathcal{L}_2$-gain is a natural generalization of the extensively studied conventional (linear) $\mathcal{L}_2$-gain property that finds application in stability analysis and $\mathcal{H}_\infty$-control for nonlinear systems. As in the conventional formulation, notions of transient and gain bounds play an integral role in the statement of the property as an input / output inequality. These bounds summarize an imposed decoupling of system behaviour into transient and asymptotic parts, each of which are important in understanding and quantifying system performance. In this work, a variational approach to the characterization of transient bounds in the presence of a fixed nonlinear gain is considered. Based on an associated dynamic programming principle for this variational characterization, a max-plus eigenvector method for approximating tight transient bounds in the presence of a nonlinear $\mathcal{L}_2$-gain bound is considered. Convergence of the associated power method is considered in some detail, whilst it is shown that significant issues remain to be addressed in the approximation of the dynamic programming evolution operators associated with the attendant finite horizon optimization problems.**

16.30 – 17.00

Idempotent Methods for Control of Diffusions

*Ben G. Fitzpatrick, Li Liu*

***Abstract*–In this paper we discuss the application of max-plus arithmetic to stochastic control problems. The dynamic programming equation is not max-plus linear in the stochastic case, but a max-plus distributivity property permits efficient value function and control computation. We illustrate the technique by controlling the van der Pol equation.**

17.00 – 17.30

Curse-of-Dimensionality-Free Control Methods for the Optimal Synthesis of Quantum Circuits

*Srinivas Sridharan, William M. McEneaney, Matthew R. James*

***Abstract*–In this article we introduce the use of a recently developed numerical method from optimal control theory to the gate synthesis problem. This technique helps avoid the curse-ofdimensionality (COD) in the spatial dimension inherent in mesh based numerical approaches to solving control problems which also arise in optimal gate synthesis. In the proposed algorithm there is a however a growth in the complexity, related to the cardinality of the discretized control set, which is managed via a pruning technique. Hence an exponential speed up in the solution to a large class of control problems on spin systems is obtained. The reduced complexity method is then applied to obtain the approximate solution to an example problem on SU(4)- a 15 dimensional system.**

## Wednesday, 7 July

### Plenary Lecture

**Room 1**

***Chair:*** *Joachim Rosenthal*

09.00 – 10.00

Codes, Trellis Representations and the Interplay of System Theory and Coding Theory

*Heide Glüsing-Lürssen*

***Abstract*–We will present state realizations (trellises) for convolutional codes and block codes and discuss their system theoretic properties. For convolutional codes we will give an application of such realizations by presenting a MacWilliams Identity which relates the weight distribution of a code to the weight distribution of the dual code. For block codes, state realizations are based on the interpretation of the code (of length *n*, say) as a set of admissible trajectories (codewords) on the time axis 0, . . . , n − 1. After discussing conventional trellis realizations, we will turn to tail-biting trellises in which the time axis is considered circular and time index arithmetic is performed modulo n. In this case the future and past of trajectories are intertwined. One particular consequence is that minimal tail-biting trellises are not unique. We will show how to obtain all minimal tail-biting trellises for a given code and discuss further properties.**

### Semiplenary Lecture

**Room 1**

***Chair:*** *William M. McEneaney*

10.30 – 11.30

Learning Algorithms for Risk-Sensitive Control

*Vivek S. Borkar*

***Abstract*–This is a survey of some reinforcement learning algorithms for risk-sensitive control on infinite horizon. Basics of the risk-sensitive control problem are recalled, notably the corresponding dynamic programming equation and the value and policy iteration methods for its solution. Basics of stochastic approximation algorithms are also sketched, in particular the 'o.d.e.' approach for its stability and convergence, and implications of asynchrony. The learning schemes give stochastic approximation versions of the traditional iterative schemes for solving dynamic programs. Two learning schemes, Q-learning and the actor-critic method, are described along with their convergence analysis. As these 'ideal' schemes suffer from 'curse of dimensionality', one needs to use function approximation as a means to beat down the dimension to manageable levels. A function approximation based scheme is described for the simpler problem of policy evaluation. Some future research directions are pointed out.**

### Semiplenary Lecture

**Room 14**

***Chair:*** *Lorenzo Finesso*

10.30 – 11.30

Challenges of Tracking Single Molecules in Live Cells

*Raimund Ober*

***Abstract*–For centuries microscopy has played an important role in biological investigations. Despite this long history, quite recently microscopy investigations of cells have undergone revolutionary developments. This is due to two independent but equally important developments. Modern**

molecular biology, and in particular the use of the green fluorescent protein, allow from the highly specific labeling of proteins in live cells. On the engineering side it is the development of highly sensitive imaging detectors, combined with computer control that allows images to be recorded with unprecedented sensitivity. This had as a result that, over the last decade, the imaging of single molecules in a live cell has become possible.

This new discipline of single molecule microscopy poses a significant number of exciting problems for engineers and mathematicians. For example, the classical notions of resolution limits for microscopes need to be re-evaluated. Current experiments in our lab and others show that distances at least one order below those predicted by Rayleigh's criterion can be determined. Estimation algorithms for locations of single molecules are the core of the analysis of most single molecule imaging approaches. The question therefore arises how well these locations can be determined. We will present an information theoretic approach to this and other problems in single molecule microscopy.

## Semiplenary Lecture

**Room 15**

***Chair:*** *Hans Zwart*

10.30 – 11.30

Coping with Time Delays in Networked Control Systems
*Hitay Özbay*

***Abstract*–In networked control systems, where controller and plant exchange information over a communication network, performance of the feedback system depends on certain properties of the communication channels. For example, packet loss, network delay and delay jitter have negative effect on networked system performance. Depending on the communication infrastructure, different mechanisms are implemented to reduce the packet loss rate and network induced delay in communication networks. In this paper, one of these mechanisms, namely, buffer/queue management is studied. It will be shown that techniques from robust control of uncertain time delay systems can be used effectively. Simpler low order controllers (PI and PID) are also considered. The effect of controller parameters on various performance metrics are illustrated.**

## Distinguished Lecturer

**Room 1**

***Chair:*** *György Michaletzky*

11.30 – 12.30

The Mathematical Challenge of Large Networks
*László Lovász*

# Thursday, 8 July

## Plenary Lecture

**Room 1**

***Chair:*** *William J. Helton*

09.00 – 10.00

Robust Control, Multidimensional Systems and Multivariable Function Theory: Commutative and Noncommutative Settings
*Joseph A. Ball, Sanne ter Horst*

***Abstract*–In the classical 1-D case there is a seamless connection between state-space (time-domain) representations and transfer-function (frequency-domain) representations for linear systems. In particular, the first results on $H^\infty$-control were developed in the frequency-domain leading to an active exchange of ideas between mathematicians with backgrounds in function theory and engineers. Eventually elegant computational algorithms for solving the standard $H^\infty$-control problem were found in terms of state-space coordinates, first in terms of a pair of coupled Riccati equations, and then completely in terms of Linear Matrix Inequalities. Here we discuss two kinds of extensions of these ideas to the context of multidimensional systems and multivariable function theory, namely: (1) the commutative case, where the transfer-function is a function of several complex variables, and (2) the noncommutative case, where the transfer-function is a function of noncommuting operator (or matrix) variables. Perhaps surprisingly, we shall see that the noncommutative setting provides a much more complete parallel with the classical case than the commutative setting. Many of the ideas of the present report are taken from our survey article [17].**

## New Developments in Stochastic System Identification
*(Invited Session)*

**Room 2**

***Organizer:*** *Yoshito Ohta*
***Chair:*** *Yoshito Ohta*

10.30 – 11.00

A Prediction-Error Identification Framework for Linear Parameter-Varying Systems
*Roland Tóth, Peter S.C. Heuberger, Paul M.J. Van den Hof*

***Abstract*–Identification of Linear Parameter-Varying (LPV) models is often addressed in an Input-Output (IO) setting using particular extensions of classical Linear Time-Invariant (LTI) prediction-error methods. However, due to the lack of appropriate system-theoretic results, most of these methods are applied without the understanding of their statistical properties and the behavior of the considered noise models. Using a recently developed series expansion representation of LPV systems, the classical concepts of the prediction-error framework are extended to the LPV case and the statistical properties of estimation are analyzed in the LPV context. In the introduced framework it can be shown that under minor assumptions, the classical results on consistency, convergence, bias and asymptotic variance can be extended for LPV predictionerror models and the concept of noise models can be clearly understood. Preliminary results on persistency of excitation and identifiability can also established.**

11.00 – 11.30

Continuous-Time Subspace Identification in Closed-Loop
*Marco Bergamasco, Marco Lovera*

***Abstract*–This paper deals with the problem of continuoustime model identification and presents a subspace-based algorithm capable of dealing with data generated by systems operating in closed-loop. The algorithm is developed by reformulating the identification problem from the continuous-time model to an equivalent one to which discrete-time subspace identification techniques can be applied. More precisely, the considered approach corresponds to the projection of the input-output data onto an orthonormal basis, defined in terms of Laguerre filters. In this framework, the PBSID subspace identification algorithm, originally developed in the case of discrete-time systems, can be reformulated for the continuoustime case. Simulation results are used to illustrate the achievable performance of the proposed approach with respect to existing methods available in the literature.**

11.30 – 12.00

Spectral Density Function under Observation Outliers
*Hideyuki Tanaka, Jaafar ALMutawa, Yoshito Ohta*

***Abstract*–This paper deals with a problem of identifying purely stochastic linear systems from stationary Gaussian processes with observation outliers. Reviewing [1], the spectral density function of the process under observation outliers is derived, and it is compared with the one free from outliers. It is shown that the estimates of the spectral density function is enormously affected by observation outliers on the frequency where the spectral density function is small.**

12.00 – 12.30

Bias-Compensated State Space Model Identification
*Kenji Ikeda, Yoshio Mogami, Takao Shimomura*

***Abstract*–A method of bias compensation in subspace identification method is proposed. The noise is assumed to be colored with 0 mean and is assumed to be uncorrelated with the input. The covariance matrix of the noise is estimated directly from the residuals instead of estimating the noise model. The proposing method becomes an iterative algorithm but it converges with order 2.**

## Linear Matrix Inequalities
*(Regular Session)*

**Room 3**

***Chair:*** *Christian Ebenbauer*

10.30 – 11.00

Linear Matrix Inequalities for Normalizing Matrices
*Christian Ebenbauer*

***Abstract*–A real square matrix is normal if it can be diagonalized by an unitary matrix. In this paper novel convex conditions are derived to decide if a matrix is similar to a normal matrix and it is shown how to use these conditions to normalize matrices. The conditions are expressed in terms of linear matrix inequalities and hence they are efficiently solvable using semidefinite programming. Since a matrix is similar to a normal matrix if and only if the matrix is diagonalizable, the present results also provide novel convex conditions for deciding if a matrix is diagonalizable or not. Some applications of these results are presented.**

11.00 – 11.30

LMI Conditions for the Stability of 2D State-Space Models
*Djillali Bouagada, Paul van Dooren*

***Abstract*–In this paper we consider the problem of stability of two-dimensional linear systems. New sufficient conditions for the asymptotic stability are derived in terms of linear matrix inequalities.**

11.30 – 12.00

Dynamic Quantizer Synthesis Based on Invariant Set Analysis for SISO Systems with Discrete-Valued Input
*Kenji Sawada, Seiichi Shin*

***Abstract*–This paper proposes analysis and synthesis methods of dynamic quantizers for linear feedback single input single output (SISO) systems with discrete-valued input in terms of invariant set analysis. First, this paper derives the quantizer analysis and synthesis conditions that clarify an optimal quantizer within the ellipsoidal invariant set analysis framework. In the case of minimum phase feedback systems, next, this paper presents that the structure of the proposed quantizer is also optimal in the sense that the quantizer gives an optimal output approximation property. Finally, this paper points out that the proposed design method can design a stable quantizer for non-minimum phase feedback systems through a numerical example.**

12.00 – 12.30

Fixed-Order Output-Feedback Control Design for LTI Systems: a New Algorithm to Reduce Conservatism
*Emile Simon, Pedro Rodriguez-Ayerbe, Cristina Stoica, Didier Dumur, Vincent Wertz*

***Abstract*–This work proposes an algorithm to reduce the conservatism of fixed-order output-feedback control design for Linear Time Invariant (LTI) systems with Linear Matrix Inequalities (LMIs)-representable objectives. Using Lyapunov theory and the Schur complement many objectives can be written as Bilinear Matrix Inequalities (BMIs), which in general are hard to solve and have a non-convex space of solutions. The classical response to this is to use LMIs reformulation of BMIs, therefore using convex subspaces of the non-convex space of all solutions and thus introducing conservatism in general. Here a new use of a change of variables is proposed, so that consecutive convex subspaces are considered iteratively. This algorithm explores further the non-convex space of solutions, leading to improved objectives with reduced conservatism.**

## Optimization Methods in Systems and Control
*(Invited Session)*

**Room 4**

***Organizer:*** *Lars Grüne*
***Chair:*** *Lars Grüne*

10.30 – 11.00

A Sparse Stability Test for Sparse Matrices
*Anders Rantzer*

***Abstract*–In the study of distributed control systems, it is of fundamental interest to understand how specifications on local interconnections influence properties of the global system. In this paper, we consider linear continuous time systems described by a sparse matrix. The property of interest is stability. In particular, for matrices with sparsity structure corresponding to a chordal graph, we show that conditions for Hurwitz stability can be written with the same sparsity structure.**

11.00 – 11.30

Delay-Optimal Global Feedbacks for Quantized Networked Event Systems
*Stefan Jerg, Oliver Junge*

***Abstract*–We extend a recent optimization based technique for the construction of globally stabilizing optimal controllers for quantized nonlinear event systems in a digital network. To this end, we assume that the plant and the controller possess synchronized clocks and that at each event the (global) time stamp is transmitted from the event generator to the controller. The new construction explicitely incorporates the delay information, rendering the controller more robust. The method is illustrated by means of the inverted pendulum in a digital loop.**

11.30 – 12.00

Efficient Model Predictive Control for Linear Periodic Systems
*Andreas Freuer, Marcus Reble, Christoph Böhm, Frank Allgöwer*

***Abstract*–This paper proposes a novel model predictive control scheme for the stabilization of constrained linear periodically time-varying systems. The results are based on an existing Model Predictive Control scheme for uncertain linear systems using linear matrix inequalities. A pre-determined periodic feedback control law is used in combination with superimposed free control moves as additional degrees of freedom. Only the additional free control moves are calculated online taking advantage of pre-computed periodic invariant sets. Two simple algorithms are presented for calculating offline ellipsoidal or polyhedral periodic invariant sets. Since only a small number of free control moves is calculated online by solving a convex optimization problem after each time period, the computational cost can be reduced significantly compared to existing schemes.**

12.00 – 12.30

Simple Homothetic Tube Model Predictive Control
*Saša V. Raković, Basil Kouvaritakis, Rolf Findeisen, Mark Cannon*

***Abstract*–This paper considers the robust model predictive control synthesis problem for constrained linear discrete time systems. The manuscript introduces a simple homothetic tube model predictive control synthesis method. The proposed method employs several novel features including: a more general parameterization of the state and control tubes based on homothety and invariance; a more flexible form of the terminal constraint set; and a relaxation of the dynamics of the sets that define the state and control tubes. Under rather mild assumptions it is demonstrated that the proposed method is computationally efficient while it induces strong system theoretic properties.**

## Real Algebraic Geometry and Applications – 2
*(Invited Session)*

**Room 6**

***Organizers:*** *William J. Helton, Pablo Parrilo*
***Chair:*** *William J. Helton*

10.30 – 11.00

It is Convexity and Positivity of Polynomials
*Pablo Parrilo*

11.00 – 11.30

Recent Progress on Obtaining Matrix Convexity when the Variables are Matrices
*William J. Helton*

***Abstract*–The talk will focus an aspect of noncommutative analysis and be designed to mesh with a four lecture tutorial surveying that topic. Especially challenging is to develop a theory of change of noncommuting variables. In classical control, eg $H^\infty$ control, reducing problems to convex ones typically requires a change of matrix variables. Matrix convex problems are now known to be equivalent to LMI problems. The goal is to develop a theory which helps delineate some possibilities for changing variables to produce an LMI. There are results in special situations along these lines. Various aspects of the work are done jointly with Jeremy Greene, Igor Klep, Victor Vinnikov and Scott McCullough.**

11.30 – 12.00

A Nullstellensatz for a Class of Two Sided Ideals of Noncommutative Polynomials
*Victor Vinnikov*

*Abstract*— We show that if a polynomial $p$ in 2d noncommuting indeterminates $x_1, \ldots, x_d, x_1^*, \ldots, x_d^*$ vanishes on all $d$ tuples of unitary matrices, then $p$ belongs to the two sided ideal in the ring of noncommutative polynomials generated by $1-x_1x_1^*, 1-x_1^*x_1, \ldots, 1-x_dx_d^*, 1-x_d^*x_d$. Similarly, if $p$ vanishes on all $d$ tuples ($d > 1$) that are spherical isometries, then $p$ belongs to the two sided ideal generated by $1-x_1^*x_1-\cdots-x_d^*x_d$. These results allow in particular to obtain final versions of the noncommutative Positivstellensatz for unitaries and for row isometries.

The first result can be proved in a fairly straightforward way using the universal property of the free group. The second result hinges on a fairly delicate analysis showing that the quotient of the ring of noncommutative polynomials by the corresponding two sided ideal is embeddable in a skew field and uses the "first fundamental theorem" of Amitsur on rational identities. In fact we establish a general Nullstellensatz for two sided ideals in the ring of noncommutative polynomials which can be "rationally resolved" and such that the quotient is embeddable in a skew field. This should have many further applications to free noncommutative (semi)algebraic geometry which has recently emerged as a major mathematical tool in systems and control for dimension independent problems, especially in relation to linear matrix inequalities.

This is a joint work with Igor Klep.

12.00 – 12.30

Relaxing LMI Domination Matricially
*Igor Klep*

*Abstract*— Given linear matrix inequalities (LMIs) $L_1$ and $L_2$ in the same number of variables it is natural to ask:

($Q_1$) when does one dominate the other, that is, does $L_1(X) \succeq 0$ imply $L_2(X) \succeq 0$?

($Q_2$) when are they mutually dominant, that is, when do they have the same solution set?

**Such problems can be NP-hard. We describe a natural relaxation of an LMI, based on substituting matrices for the variables $x_j$. With this relaxation, the domination questions ($Q_1$) and ($Q_2$) have elegant answers, indeed reduce to semidefinite programs (SDP), which we show how to construct. For our "matrix variable" relaxation a positive answer to ($Q_1$) is equivalent to the existence of matrices $V_j$ such that**

$$L_2(x) = V_1^* L_1(x) V_1 + \cdots + V_\mu^* L_1(x) V_\mu. \qquad (A_1)$$

**As for ($Q_2$) we show that $L_1$ and $L_2$ are mutually dominant if and only if, up to certain redundancies described in the paper, $L_1$ and $L_2$ are unitarily equivalent.**

**An observation at the core of this talk is that the relaxed LMI domination problem is equivalent to a classical problem. Namely, the problem of determining if a linear map $\tau$ from a subspace of matrices to a matrix algebra is "completely positive".**

**This is a joint work with J. William Helton and Scott McCullough.**

## The Semigroup Approach to DPS

*(Invited Session)*

**Room 7**

***Organizer:*** *George Weiss*
***Chair:*** *George Weiss*

10.30 – 11.00

Analytic Properties of Matrix Riccati Equation Solutions
*Ruth F. Curtain, Leiba Rodman*

***Abstract*–For matrix Riccati equations of platoontype systems and of systems arising from PDEs, assuming the coefficients are analytic functions in a suitable domain, the analyticity of the stabilizing solution is proved under various hypotheses. In addition, general results on the analytic behavior of stabilizing solutions are developed.**

11.00 – 11.30

Structurally Damped Plate Equations with Random Point Force
*Roland Schnaubelt*

***Abstract*— In this paper we consider structurally damped plate equations with point and distributed random forces which could be interpreted as random controls. In order to treat space dimensions more than one, we work in the setting of $L^p$–spaces with (possibly small) $p \in (1, 2)$. We establish existence, uniqueness and regularity of mild and weak solutions to the stochastic equations employing recent theory for stochastic evolution equations in $L^p$ spaces. The proof further requires inter- and extrapolation spaces for the operator matrix solving the determiniastic problem. This is joint work with Mark Veraar (TU Delft).**

11.30 – 12.00

A Spectral Approach to the Null-Controllability of Diffusion Processes
*Gérald Tenenbaum, Marius Tucsnak*

This work is concerned with the study of null-controllability for a class of infinite dimensional systems described by abstract parabolic equations of the form

$$\text{(1)} \qquad \dot{w} = Aw + Bu, \ w(0) = z,$$

where $A$ is a negative operator in a Hilbert space $X$ and, say, the operator $B$ maps the input space $U$ (also a Hilbert space) into a space larger than $X$, i.e. $B$ is an *unbounded input operator.* To study the null-controllability of the above system, a new tool brought up in [3] is an abstract sufficient condition for null-controllability, inspired by the method introduced in [1]—see also Lebeau and Zuazua [2].

In this work, our initial aim consists, in an abstract setting, in relaxing the assumptions on the control operator $B$ with respect to the existing literature, together with simplifying some proofs and the form of the constants involved in the control cost estimates. Our second purpose is, in the case when $A = -A_0^\eta$, where $A_0$ is the Dirichlet Laplacian in a rectangular domain $\Omega$ and $\eta > 1/2$, to provide an alternative way to check the Lebeau-Robbiano spectral condition. We show, in this particular case, that the sophisticated Carleman and interpolation inequalities used in [1] may be replaced by a simple result of Turán [6].

12.00 – 12.30

Observers for DPS Back and Forth in Time
*George Weiss, Karim Ramdani, Marius Tucsnak*

***Abstract*— Let $A$ be the generator of a strongly continuous semigroup $\mathbb{T}$ on the Hilbert space $X$, and let $C$ be a linear operator from $\mathcal{D}(A)$ to another Hilbert space $Y$ (possibly unbounded with respect to $X$, not necessarily admissible). We consider the problem of estimating the initial state $z_0 \in \mathcal{D}(A)$ (with respect to the norm of $X$) from the output function $y(t) = C\mathbb{T}_t z_0$, given for all $t$ in a bounded interval $[0, \tau]$. We introduce the concepts of estimatability and backward estimatability for $(A, C)$ (in a more general way than currently available in the literature), we introduce forward and backward observers, and we provide an iterative algorithm for estimating $z_0$ from $y$. This algorithm generalizes various algorithms proposed recently for specific classes of systems and it is an attractive alternative to methods based on inverting the Gramian. Our results lead also to a very general formulation of Russell's principle, i.e., estimatability and backward estimatability imply exact observability. This general formulation of the principle does not require $\mathbb{T}$ to be invertible.**

## Riccati and Sylvester-Equations

*(Regular Session)*

**Room 8**

***Chair:*** *Timo Reis*

10.30 – 11.00

Lur'e Equations and Singular Optimal Control
*Timo Reis*

***Abstract*–In this work we give an overview about Lur'e matrix equations, linear-quadratic infinite time horizon optimal control problems and their connections to the eigenstructure of certain even matrix pencils. We characterize the set of solutions in terms of deflating subspaces of even matrix pencils. In particular, it is shown that these special solutions can be constructed deflating subspaces of even matrix pencils.**

11.00 – 11.30

Reduction of State Variables Based on Regulation and Filtering Performances
*Hidenori Shingin, Yoshito Ohta*

***Abstract*–This paper provides a component analysis for the state variables of stable linear disrete-time systems based on the control and estimation performance criteria. In the optimal regulation and filtering problems, the trade-offs between the dimension of the control or estimation law and degree of performance degenerations are invariants given as the eigenvalues of the matrices depending on the solutions of both Lyapunov and Riccati equations. This analysis shows the dominant components of the state variables which have major contribution to enhance the performances.**

11.30 – 12.00

An Explicit Dynamic Programming Solution for a Decentralized Two-Player Optimal Linear-Quadratic Regulator

*John Swigart, Sanjay Lall*

***Abstract*–We develop optimal controller synthesis algorithms for decentralized control problems, in which individual sub- systems are connected over a network. We consider a simple information structure, consisting of two in- terconnected linear systems, and construct the optimal controller subject to a decentralization constraint via a novel dynamic programming method. We provide ex- plicit state-space formulae for the optimal controller, and show that each player has to do more than simply esti- mate the states that they cannot observe. In other words, the simplest separation principle does not hold for this decentralized control problem.**

12.00 – 12.30

A State-Space Solution of Bilateral Diophantine Equations over $RH_\infty$

*Maxim Kristalny, Leonid Mirkin*

***Abstract*–This paper studies a class of real-rational matrix bilateral Diophantine equations (BDE) arising in numerous control problems. A necessary and sufficient solvability condition is derived in terms of state-space realizations of rational matrices involved in the equation. This condition is given in terms of a constrained matrix Sylvester equation and is numerically tractable. An explicit state-space parametrization of all solutions is also derived. This parameterization effectively includes two parameters: one is a "standard" $RH_\infty$ parameter and another one arises if the Sylvester equation is non-uniquely solvable. A condition, in terms of zeros of rational matrices involved in the BDE, is found under which the Sylvester equation has a unique solution and, hence, the parametrization is affine in a single $RH_\infty$ parameter.**

## Network Stability

*(Regular Session)*

**Room 9**

***Chair:*** *Ulf T. Jönsson*

10.30 – 11.00

Primal and Dual Criteria for Robust Stability

*Ulf T. Jönsson*

***Abstract*–Primal and dual formulations of stability criteria based on integral quadratic constraints (IQC) are discussed. The foundation for IQC based stability analysis is to use a convex cone of multipliers to characterize the uncertainty in a system. The primal and dual stability criteria are formulated as convex feasibility tests involving the nominal dynamics and multipliers from the cone and the polar cone, respectively. The motivation for introducing the dual is that it provides additional insight into the stability criterion and is sometimes easier to use than the primal.**

**The case considered in this paper is when the uncertainty represents the interconnection of a complex network. The multipliers are used to describe characteristic properties of the network such as the spectral location or the structure of the underlying graph.**

11.00 – 11.30

Guaranteed Cost for Control of Networked Control Systems with Small Time-Varying Delays

*Marc Jungers, Laurentiu Hetel, Jamal Daafouz*

***Abstract*–This paper deals with the control design of a networked control systems subject to small time-varying delays, which takes into account the performance aspect. The considered approach consists in using a limited Taylor series expansion for the uncertain parameter exponential matrix. An optimization problem involving LMI constraints is proposed to obtain the minimal quadratic upper bound of the guaranteed cost. An example illustrates our approach and is the base for a extended discussion.**

11.30 – 12.00

A Novel Discontinuous Lyapunov Functional Approach to Networked-Based Stabilization

*Kun Liu, Vladimir Suplin, Emilia Fridman*

***Abstract*–This paper presents a new stability analysis of Networked Control Systems (NCSs), where the sampling and the constant network-induced delays are taken into account. The new method is inspired by discontinuous Lyapunov functionals that were recently introduced for sampled-data systems in [1] (in the framework of impulsive system representation) and in [2] (in the framework of input delay approach). However, extensions of the above Lyapunov constructions to NCSs lead to complicated conditions, which become conservative if the network-induced delays is not small. In the present paper a novel discontinuous Lyapunov functional is introduced, which is based on the application of the Wirtinger type inequality. This functional leads to efficient stability conditions in terms of Linear Matrix Inequality (LMIs). The new stability analysis is applied to sampled-data stabilization by using artificial delay.**

12.00 – 12.30

A Multichannel IOpS Small-Gain Theorem for Large Scale Systems

*Rudolf Sailer, Fabian Wirth*

***Abstract*–This paper extends known results on the stability analysis of interconnected systems. In particular, a small-gain theorem for the interconnection of an arbitrary number of systems via communication channels is presented. Here the communication between the subsystems is over a delayed, possibly lossy communication channel. To this end, a notion of input-to-output stability for functional differential equations is applied.**

## Stability

*(Regular Session)*

**Room 10**

***Chair:*** *Svyatoslav S. Pavlichkov*

10.30 – 11.00

Further Remarks on Global Stabilization of Generalized Triangular Systems

*Sergey Dashkovskiy, Svyatoslav S. Pavlichkov*

***Abstract*— We remove the assumption on $C^\nu$ - smoothness from the main theorem in work [7] and show how to modify the argument from [7] in order to obtain the same result on global asymptotical stabilization when the dynamics satisfies the local Lipschitz condition in general and is of class $C^1$ around the equilibrium only.**

11.00 – 11.30

Invariance Results Involving Non-Monotonic Lyapunov Functions with Applications
*Anthony N. Michel, Ling Hou*

***Abstract*–The invariance result for asymptotic stability of autonomous systems involves positive definite Lyapunov functions which are non-increasing along the systems' motions. We establish a result for discontinuous non-autonomous systems with positive definite Lyapunov functions which are nonincreasing only on an unbounded discrete set, resulting in nonmonotonic Lyapunov functions. We show that the invariance result for asymptotic stability reduces to the invariance result reported herein. We apply this result in the stabilization of conservative mechanical systems.**

11.30 – 12.00

A New Characterisation of Exponential Stability
*Elena Panteley, Antonio Loría*

***Abstract*–We present a new characterization of exponential stability for nonlinear systems in the form of Lyapunov functions which may be upper and lower bounded by monotonic functions satisfying a growth order relationship rather than being polynomials of the state's norm. In particular, one may allow for Lyapunov functions with arbitrary weakly homogeneous bounds.**

12.00 – 12.30

Sufficient Conditions for Local Asymptotic Stability and Stabilization for Discrete-Time Varying Systems
*Angeliki Stamati, John Tsinias*

***Abstract*–The purpose of this paper is to establish sufficient conditions for local asymptotic stability and feedback stabilization for discrete-time systems with time depended dynamics. Our main results constitute generalizations of those developed by same authors in a recent paper, for the case of continuoustime systems.**

## Port-Hamiltonian Systems
*(Regular Session)*

**Room 11**

***Chair:*** *Arjan J. van der Schaft*

10.30 – 11.00

Port-Hamiltonian Systems on Open Graphs
*Arjan J. van der Schaft, Bernhard M. Maschke*

***Abstract*–In this talk we discuss how to define in an intrinsic manner port-Hamiltonian dynamics [3] on open graphs. Open graphs are graphs where some of the vertices are boundary vertices (terminals), which allow interconnection with other systems. We show that a directed graph carries two natural Dirac structures [3], called the Kirchhoff-Dirac structure and the vertex-edge Dirac structure. The port-Hamiltonian dynamics corresponding to the Kirchhoff-Dirac structure is exemplified by the dynamics of an RLC-circuit, see also [5], [4]. The port-Hamiltonian dynamics corresponding to the vertex-edge Dirac structure is illustrated by coordination control, in which case there is dynamics associated to every vertex and to every edge, and by standard consensus algorithms where there is dynamics associated to every vertex while every edge corresponds to a resistive relation.**

11.00 – 11.30

Adaptive Control of Port-Hamiltonian Systems
*Daniel A. Dirksz, Jacquelien M.A. Scherpen*

***Abstract*–In this paper an adaptive control scheme is presented for general port-Hamiltonian systems. Adaptive control is used to compensate for control errors that are caused by unknown or uncertain parameter values of a system. The adaptive control is also combined with canonical transformation theory for port-Hamiltonian systems. This allows for the adaptive control to be applied on a large class of systems and for being included in the port-Hamiltonian framework.**

11.30 – 12.00

Model Reduction of Port-Hamiltonian Systems as Structured Systems
*Rostyslav V. Polyuga, Arjan J. van der Schaft*

***Abstract*–The goal of this work is to demonstrate that a specific projection-based model reduction method, which provides an $H_2$ error bound, turns out to be applicable to port- Hamiltonian systems, preserving the *port-Hamiltonian structure* for the reduced order model, and, as a consequence, *passivity*.**

12.00 – 12.30

Modeling for Control of an Inflatable Space Reflector, the Linear 2-D Case
*Thomas Voss, Jacquelien M.A. Scherpen*

***Abstract*–In this paper we develop a mathematical model for the dynamics of a linear plate with piezoelectric actuation. This model can then be used to design controllers with the goal of achieving a desired shape of the plate. This control scheme can be used for several applications, e.g., vibration control in structures or shape control for high precision structures like inflatable space reflectors. The starting point of the control design is modeling for control. We will do this in the framework of port-Hamiltonian (pH) modeling, since the pH modeling framework has very nice properties which can be exploited if one wants to design a controller for a specific task. One property for example is that it facilitates modeling multi physics systems or systems which consist of several systems by first modeling all parts separate and then interconnecting them. This is possible because any interconnection of pH systems yields again a pH system. Hence, the pH framework is useful for our multi-domain modeling purpose.**

## Stochastic Control – 1
*(Invited Session)*

**Room 13**

***Organizers:*** *Bozenna Pasik-Duncan, Tyrone E. Duncan*
***Chair:*** *Bozenna Pasik-Duncan*

10.30 – 11.00

Social Certainty Equivalence in Mean Field LQG Control: Social, Nash and Centralized Strategies
*Minyi Huang, Peter E. Caines, Roland P. Malhamé*

***Abstract*–We study social decision problems and Nash games for a class of linear-quadratic-Gaussian (LQG) models with N decision makers possessing different dynamics. For the social decision case, the basic objective is to minimize a social cost as the sum of N individual costs containing mean field coupling, and the exact social optimum requires centralized information. Continuing from the previous work (Huang, Caines, and Malhamé, 2009 Allerton Conference), we develop decentralized cooperative**

optimization so that each agent only uses its own state and a function which can be computed off-line.We prove asymptotic social optimality results with general vector individual states and continuum dynamic parameters. In finding the asymptotic social optimum, a key step is to let each agent optimize a new cost as the sum of its own cost and another component capturing its social impact on all other agents. We also discuss the relationship between the socially optimal solution and the so-called Nash Certainty Equivalence (NCE) based solution presented in previous work on mean field LQG games, and for the NCE case we illustrate a cost blow-up effect due to the strength of interaction exceeding a certain threshold.

11.00 – 11.30

Idempotent Algorithms for Continuous-Time Stochastic Control
*Hidehiro Kaise, William M. McEneaney*

*Abstract*–**Previously, idempotent methods have been found to be extremely fast for solution of dynamic programming equations associated with deterministic control problems. The original methods exploited the idempotent (e.g., max-plus) linearity of the associated semigroup operator. However, it is now known that the curse-ofdimensionality-free idempotent methods do not require this linearity, and may be used to solve some classes of stochastic control problems. The key is the use of the idempotent distributive property. This was previously demonstrated for a class of discrete-time stochastic control problems. Here, we extend this approach to a class of continuous-time stochastic control problems.**

11.30 – 12.00

Tuning the TCP Timeout Mechanism in Wireless Networks to Maximize Throughput via Stochastic Stopping Time Methods
*George Papageorgiou, John S. Baras*

*Abstract*–**We present an optimization problem that aims to maximize the throughput of a Transmission Control Protocol (TCP) connection between two nodes in a wireless ad-hoc network. More specifically, a persistent TCP connection is established between two nodes that are one hop away in a wireless unslotted Aloha network. The optimization is over the TCP timeout period, i.e. the problem is to find the optimal waiting period before the TCP sender declares a timeout event in the absence of a received acknowledgment for a transmitted packet. The problem is formulated as an optimal stopping problem. In the absence of a tractable analytical solution to the problem, a numerical method is proposed to achieve performance improvement of the system.**

12.00 – 12.30

Control of Linear Systems with Fractional Brownian Motions
*Tyrone E. Duncan, Bozenna Pasik-Duncan*

*Abstract*–**In this paper a control problem for a multidimensional linear stochastic system with a vector of fractional Brownian motions and a cost functional that is quadratic in the state and the control is solved. An optimal control is given explicitly using the (Riemann-Liouville) fractional calculus and the control is shown to be the sum of a prediction of the optimal system response to the future fractional Brownian motion and the well known linear feedback control for the deterministic linear-quadratic control problem. It is noted that the methods to obtain an optimal control extend to other noise processes with continuous sample paths and finite second moments.**

## Algebraic Systems Theory, Behaviors, and Codes: Recent Approaches to New System Classes
*(Invited Session)*

**Room 14**

***Organizers:*** *Eva Zerz, Heide Glüsing-Lürssen*
***Chair:*** *Eva Zerz*

10.30 – 11.00

Elimination, Fundamental Principle and Duality for Analytic Linear Systems of Partial Differential-Difference Equations with Constant Coefficients
*Henri Bourlès, Ulrich Oberst*

*Abstract*–**Partial differential-difference equations are the multidimensional generalization of ordinary delay-differential equations. We investigate behaviors of analytic signals governed by equations of this type, i.e., solution modules of linear systems with constant coefficients of such equations, and especially the problems of elimination and duality. The first concerns the question whether the images of behaviors are again behaviors and in particular the existence of solutions of inhomogeneous linear systems which satisfy the obvious necessary compatibility conditions. Duality refers to the determination of the module of equations by the behavior. Our theory is presently restricted to analytic signals because the proofs make substantial use of the Stein algebra of multivariate entire functions and of Stein modules over it, but the extension to smooth or distributional signals is of course an important task for the future. We especially prove the validity of elimination for delay-differential equations with incommensurate delays and thus solve, for analytic signals, an open problem stated by Glüsing-Lürssen, Vettori and Zampieri. Duality is expressed and derived by means of the polar theorem for locally convex spaces in duality. Gluesing-Luerssen's rather complete and seminal behavioral theory of delay-differential equations with commensurate delays relies on the fact that the appropriate ring of operators is a Bezout domain and especially coherent. Coherence of the relevant rings of operators in the more general situations is important, but has not yet been proven. Further contributors to the module theoretic or behavioral approach to delay-differential equations are Fliess, Habets, Mounier, Rocha, Willems et al.**

11.00 – 11.30

Symmetries, Parametrizations and Potentials of Multidimensional Linear Systems
*Thomas Cluzeau, Alban Quadrat*

*Abstract*–**Within the algebraic analysis approach to linear systems theory, the purpose of this paper is to study how left D- homomorphisms between two finitely presented left D-modules associated with two linear systems induce natural transformations on the autonomous elements of the two systems and on the potentials of the parametrizations of the parametrizable subsystems. Extension of these results are also considered for linear systems inducing a chain of successive parametrizations.**

11.30 – 12.00

Degree Structures of Polynomial Vector Modules with Applications to Systems over Fields and Rings
*Margreta Kuijper*

***Abstract*— In this paper we consider polynomial vector modules, i.e., modules in $\mathcal{R}[x]^q$. We are interested in integer invariants of such modules. In the case that $\mathcal{R}$ is a field, one such integer invariant is the "'McMillan degree"' of a module. We consider the wellknown statement that the McMillan degree of a row reduced polynomial matrix equals the sum of its row degrees. We reformulate this statement as a relationship between minimal Gröbner bases of $M$ under different monomial orders (POT and TOP). We investigate the extension of this result to weighted monomial orders and to the case that $\mathcal{R}$ is a finite ring of the type $\mathbb{Z}_{p^r}$, where $p$ is a prime integer and $r$ is a positive integer. These issues are relevant and fundamental to various applications involving codes and sequences over $\mathbb{Z}_{p^r}$.**

12.00 – 12.30

On Periodic Solutions of Linear Difference Equations
*Eva Zerz*

***Abstract*–We study systems of linear difference equations with constant coefficients in a commutative quasi-Frobenius ring *F*, that is, *F* is Noetherian and self-injective. For instance, *F* could be a field or a residue class ring of the integers. Given a positive integer *p*, we first answer the following basic questions: Does there exist a *p*-periodic solution? When are all solutions *p*-periodic? Then we address the more interesting question of how to determine candidates for the period *p*. We characterize strong autonomy (i.e., finitely many initial data) and weak autonomy (i.e., no free variables), which are nonequivalent concepts, in general. If *F* is finite, all trajectories of a strongly autonomous system eventually become periodic, and we characterize the case where they are purely periodic (i.e., no pre-period), as well as the minimal period in this case. These methods can be applied to periodically time-varying systems as studied by Kuijper/Willems and Aleixo/Polderman/Rocha, and the question whether a *p*-periodic system admits (only) *p*-periodic solutions can be tackled using the known lifting technique to rewrite a periodic system as an equivalent shiftinvariant system.**

## Geometric Control Theory for Linear Systems–1
*(Mini-Course)*

**Room 15**

***Organizers:*** *Giovanni Marro, Fabio Morbidi, Lorenzo Ntogramatzidis, Domenico Prattichizzo*

10.30 – 12.30

Geometric Control Theory for Linear Systems
*Giovanni Marro, Fabio Morbidi, Lorenzo Ntogramatzidis, Domenico Prattichizzo*

***Abstract*–This paper reviews in a condensed form the main tools and results of the geometric approach developed in the last forty years. Because of the vastness of the subject, this tutorial does not pretend to be exhaustive, and more emphasis will be given to selected topics and to the related computational tools. The authors hope their effort to provide a unified view of geometric control theory may be profitable to awake renewed interest in this research field.**

## Semiplenary Lecture

**Room 1**

***Chair:*** *Michael A. Demetriou*

14.00 – 15.00

Dynamic "Magic" Graphs in Cooperative Networked Systems
*John S. Baras*

## Semiplenary Lecture

**Room 14**

***Chair:*** *Tryphon T. Georgiou*

14.00 – 15.00

Orthogonal Rational Functions and Non-Stationary Stochastic Processes: a Szegö Theory
*Laurent Baratchart*
*(based on joint work with L. Golinskii, S. Kupin, M. Olivi and V. Lunot)*

***Abstract*–We present a generalization of Szegö theory of orthogonal polynomials on the unit circle to orthogonal rational functions. Unlike previous results, the poles of the rational functions may tend to the unit circle under smoothness assumptions on the density of the measure. Just like the Kolmogorov-Krein- Szegö theorem may be interpreted as an asymptotic estimate of the prediction error for stationary stochastic processes, the present theory yields an asymptotic estimate of the prediction error for certain, possibly nonstationary, stochastic processes. The latter admit a spectral calculus where the time-shift corresponds to multiplication by elementary Blaschke products of degree 1 (that reduce to multiplication by the independent variable in the stationnary case). When the poles of the best predictor tend to a point on the unit circle where the spectral density is nonzero, the prediction error goes to zero, i.e. the process is asymptotically deterministic.**

## Semiplenary Lecture

**Room 15**

***Chair:*** *Andrea Gombani*

14.00 – 15.00

Mathematical Finance with Heavy-Tailed Distributions
*Mathukumalli Vidyasagar*

## Stochastic Adaptive Systems
*(Regular Session)*

**Room 2**

***Chair:*** *Mario di Bernardo*

15.30 – 16.00

Synchronization and Pinning Control of Networks via Adaptation and Edge Snapping
*Pietro DeLellis, Mario di Bernardo, Maurizio Porfiri*

***Abstract*–In this paper, we propose novel adaptive pinning control strategies for synchronization of complex networks. The novelty of theses approaches is the adaptive selection of pinned nodes along with the fully decentralized adaptation of the coupling and control gains. The effectiveness of the proposed strategies is validated with numerical simulations on a testbed example.**

16.00 – 16.30

Networked Adaptive Model Predictive Control
*João M. Lemos*

***Abstract*–This paper presents a neighborhood based networked predictive adaptive controller that is suitable for control of multivariable systems made of subsystems that interact sequentially and on its demonstration using simulations in a detailed nonlinear model of a water delivery canal. Furthermore some convergence properties of the adaptive algorithm are proved.**

**According to the approach followed, the overall system is decomposed in local systems. To each local system, a local adaptive predictive controller that manipulates its input is associated. In order to improve the overall performance, communication between local controllers is provided through feedforward terms from adjacent local systems.**

16.30 – 17.00

Approximate Solution to Nonlinear Optimal Regulator Problem Using Quantum and Stochastic Theories
*Yuki Nishimura, Yuji Wakasa, Kanya Tanaka*

***Abstract*–This paper proposes a new constraction scheme of nonlinear optimal regulator by using two methods. Nishimura and Yamashita has introduced the method of obtaining approximate Lyapunov functions for deterministic and stochastic systems, which is based on difference apporximation with directions and quantization of Markov processes. On the other hand, Itami has proposed the method replacing the problem of obtaining nonlinear optimal regulators by the issue of solving Schrödinger equations. We combine above two schemes for constructing our new method.**

17.00 – 17.30

A New Unscented Kalman Filter with Higher Order Moment-Matching
*Ksenia Ponomareva, Paresh Date, Zidong Wang*

***Abstract*–This paper is concerned with filtering nonlinear multivariate time series. A new approximate Bayesian algorithm is proposed which generates sample points and corresponding probability weights that match exactly the predicted values of average marginal skewness and average marginal kurtosis of the unobserved state variables, in addition to matching their mean and the covariance matrix. The performance of the algorithm is illustrated by an empirical example of yield curve modelling with real financial market data. Results show an improvement in accuracy in comparison with extended Kalman filter (EKF) and traditional unscented Kalman filter (UKF).**

## Algebraic Systems
*(Regular Session)*

**Room 3**

***Chair:*** *Tobias Brüll*

15.30 – 16.00

Linear Quadratic Optimal Control, Dissipativity, and Para-Hermitian Matrix Polynomials
*Tobias Brüll*

***Abstract*–In this paper we will look at two results in which a special para-Hermitian matrix polynomial appears in linear quadratic systems theory. The first result constitutes the first step in a dissipativity check. The second result shows that dissipativity is equivalent to the solvability of the infinitehorizon linear quadratic optimal control problem and that its solutions are given by the behavior specified by the special para-Hermitian matrix polynomial. The results can be used to derive efficient eigenvalue methods for linear first-order statespace systems.**

16.00 – 16.30

Algebraic Properties of Riccati Equations
*Ruth F. Curtain*

***Abstract*— In this paper we examine the question when the LQR Riccati equation for matrices with components in a subalgebra $\mathfrak{A}$ of $\mathcal{L}(H)$, where $H$ is a Hilbert space, will have a unique nonnegative exponentially stabilizing solution with components in $\mathfrak{A}$. We give counterexamples to results claimed in the literature and some positive results for $2 \times 2$ matrices. In addition, we pose a conjecture and an algebraic problem.**

16.30 – 17.00

Parametrization of Stabilizing Controllers with Fixed Precompensators
*Kazuyoshi Mori*

***Abstract*–In the framework of the factorization approach, we give a parameterization of a class of stabilizing controllers. This class is characterized by some fixed strictly causal precompensators. As applications, we present the parameterization of all causal stabilizing controllers including the some fixed number or more integrators, and the parameterization of all strictly causal stabilizing controllers which has the some fixed number or more delay operators.**

17.00 – 17.30

Output Regulation of Distributed Parameter Systems with Time-Periodic Exosystems
*Lassi Paunonen, Seppo Pohjolainen*

***Abstract*–In this paper the output regulation of a linear distributed parameter system with a nonautonomous periodic exosystem is considered. It is shown that the solvability of the output regulation problem can be characterized by an infinite- dimensional Sylvester differential equation. Conditions are given for the existence of a controller solving the regulation problem along with a method for its construction.**

## New Mathematical Methods in Multidimensional Systems Theory – 3
*(Invited Session)*

**Room 4**

***Organizers:*** *Alban Quadrat, Thomas Cluzeau*
***Chair:*** *Alban Quadrat*

15.30 – 16.00

Conley Index Theory
*Mohamed Barakat, Stanislaus Maier-Paape*

***Abstract*–Conley's index theory provides powerful tools to prove either the existence or the nonexistence of connecting orbits between equilibria of the dynamical systems under consideration. Conley's idea was to relate the local and the global topological properties of the dynamical system by an algebraic object called the connection matrix. The structure of this matrix imposes serious restrictions on the possible configurations of local and global topological data. These restrictions can now be utilized to derive unknown properties of the system out of known ones.**

16.00 – 16.30

The Significance of Gabriel Localization for Stability and Stabilization of Multidimensional Input/Output Behaviors
*Ulrich Oberst*

***Abstract*–Serre (1953) was the first who considered categories of groups up to negligible ones, negligibility being determined by the considered context. Gabriel in his thesis (1962) developed this idea into a complete theory of quotient categories, rings and modules which is called Gabriel localization. This theory was nicely exposed by Stenström (1975). The author has recently observed that this theory is a valuable tool for stability and stabilization of multidimensional behaviors where a finitely generated multivariate polynomial torsion module is considered negligible if its characteristic variety has points in a preselected stability region only or, equivalently, if its associated autonomous behavior is stable, i.e., has polynomial-exponential solutions with frequencies in this stability region only. Via the Integral Representation Formula of Ehrenpreis/Palamodov corresponding properties hold for all trajectories of the behavior. In the one-dimensional standard cases stability signifies asymptotic stability. In our approach to output feedback stabilization of multidimensional systems almost direct decompositions, i.e., direct sum decompositions up to negligible modules, are essential. Quadrat had observed the significance of direct sum decompositions in stabilization theory. These decompositions are usually hidden in coprime factorizations of transfer matrices which, however, do not always exist. Bisiacco, Valcher and Napp Avelli studied almost direct decompositions for two-dimensional polynomial modules and behaviors, but without using localization theory. This paper explains Gabriel's localization and quotient modules and their use in multidimensional stabilization theory. It also contains a new algorithm for the computation of the (Gabriel) quotient module of a finitely generated torsionfree module over a multivariate polynomial ring. This algorithm can also be used for the computation of Willems closures of such modules and thus generalizes work of Shankar, Sasane, Napp Avelli, van der Put et al.. It is also useful for the computation of the purity filtration of a finitely generated polynomial torsion module which is the subject of Barakat's talk at this conference where also the history of this filtration is discussed.** **The author gratefully acknowledges financial support of the Austrian FWF.**

16.30 – 17.00

Purity Filtration and the Fine Structure of Autonomy
*Mohamed Barakat*

***Abstract*— This paper announces a constructive setup for homological algebra (of categories of finitely presented modules) in which the CARTAN-EILENBERG resolution of complexes and a particular GROTHENDIECK spectral sequence can be used to compute the purity filtration of a module $M$ (associated to a system $\Sigma$). The purity filtration yields the fine structure of the torsion submodule of $M$, which corresponds to the autonomous part of the system $\Sigma$ obstructing its controlability.**

17.00 – 17.30

Controlled Invariant Varieties of Polynomial Control Systems
*Eva Zerz, Sebastian Walcher, Fadime Güçlü*

***Abstract*–We study input-affine control systems with polynomial nonlinearity. A variety V is said to be controlled invariant if there exists a feedback law of polynomial type that causes the closed loop system to have V as an invariant variety, which means that any trajectory starting in V will remain there for all times. Using the theory of Gröbner bases, we show (under certain conditions on the given representation of V) how to constructively decide whether a given variety is controlled invariant for a given system, and if so, how to determine all feedback laws achieving the task.**

## Real Algebraic Geometry and Applications – 3
*(Invited Session)*

**Room 6**

***Organizers:*** *William J. Helton, Pablo Parrilo*
***Chair:*** *William J. Helton*

15.30 – 16.00

A Class of Forms which are PSD iff are SOS
*Carla Fidalgo, Alexander Kovačec*

By a *diagonal minus tail* form (of even degree) we understand a real homogeneous polynomial $F(x_1,\dots,x_n) = F(\underline{x}) = D(\underline{x}) - T(\underline{x})$, where the *diagonal* part $D(\underline{x})$ is a sum of terms of the form $b_i x_i^{2d}$ with all $b_i \geq 0$ and the *tail* $T(\underline{x})$ a sum of terms $a_{i_1 i_2 \dots i_n} x_1^{i_1} \dots x_n^{i_n}$ with $a_{i_1 i_2 \dots i_n} > 0$ and at least two $i_\nu \geq 1$. We show that an arbitrary change of the signs of the tail terms of a positive semidefinite diagonal minus tail form will result in a sum of squares (sos) of polynomials. The work uses Reznick's theory of agiforms [Re] and gives easily tested sufficient conditions for a form to be sos; one of these is piecewise linear in the coefficients of a polynomial and reminiscent of Lassere's recent conditions [La] but proved in a completely different manner.

16.00 – 16.30

Positivity in Power Series Rings
*Salma Kuhlmann*

***Abstract*–We extend and generalize the results of Scheiderer (2006) on the representation of polynomials nonnegative on two-dimensional basic closed semialgebraic sets. Our extension covers some situations where the defining polynomials do not satisfy the transversality condition. Such situations arise naturally when we consider semialgebraic sets invariant under finite group actions.**

16.30 – 17.00

Relationship between Nonnegative Forms, Convex Forms and Sums of Squares: Faces and Volumes
*Grigoriy Blekherman*

***Abstract*–Sums of Squares (SOS) relaxations are often used as a substitute for testing whether a polynomial is nonnegative. Testing whether a polynomial is SOS is a Semi-definite Programming problem and thus computationally tractable. We use techniques from convex geometry to study the relationship between sums of squares and non-negative polynomials. We will present results about the boundary structure and quantitative relationship between SOS and non-negative polynomials, which allow us to understand the quality of SOS relaxations. We use similar techniques to study the relationship between convex and non-negative forms. Although we show that there exist convex forms that are not sums of squares, there are currently no explicit examples.**

17.00 – 17.30

Semidefinite Representation of Convex Hulls of Rational Varieties
*Didier Henrion*

***Abstract*–Using elementary duality properties of positive semidefinite moment matrices and polynomial sum-of-squares decompositions, we prove that the convex hull of rationally parameterized algebraic varieties is semidefinite representable (that is, it can be represented as a projection of an affine section of the cone of positive semidefinite matrices) in the case of (a) curves; (b) hypersurfaces parameterized by quadratics; and (c) hypersurfaces parameterized by bivariate quartics; all in an ambient space of arbitrary dimension.**

## Operator Theoretic Approaches to DPS
*(Invited Session)*

**Room 7**

***Organizer:*** *George Weiss*
***Chair:*** *George Weiss*

15.30 – 16.00

Operator Splitting and Evolution Equations
*Andras Batkai, Petra Csomos, Balint Farkas, Klaus-Jochen Engel, Gregor Nickel*

16.00 – 16.30

The Weiss Conjecture and Katos Method for the Navier-Stokes Equations
*Bernhard H. Haak, Peer Chr. Kunstmann*

***Abstract***–**We investigate Kato's method for parabolic equations with a quadratic non-linearity in an abstract form. We extract several properties known from linear systems theory which turn out to be the essential ingredients for the method. We give necessary and sufficient conditions for these conditions and provide new and more general proofs, based on real interpolation. In application to the Navier-Stokes equations, our approach unifies several results known in the literature, partly with different proofs.**

16.30 – 17.00

The Reciprocal Symmetry in State/Signal Systems in Continuous Time
*Olof J. Staffans*

***Abstract***–**The notion of reciprocity is well-known in circuit theory: if a linear passive time-invariant circuit does not contain any gyrators, then it is reciprocal in the standard input/state/output sense, i.e., the impedance and conductance transfer functions are congruent to their adjoints. Here we extend this notion to the class of all (possibly infinite-dimensional) state/signal systems in continuous time.**

17.00 – 17.30

An $H_\infty$ Calculus of Admissible Operators
*Hans Zwart*

***Abstract*— Given a Hilbert space and the generator $A$ of a strongly continuous, exponentially stable, semigroup on this Hilbert space. For any $g(-s) \in \mathcal{H}_\infty$ we show that there exists an infinite-time admissible output operator $g(A)$. If $g$ is rational, then this operator is bounded, and equals the "normal" definition of $g(A)$. In particular, when $g(s) = 1/(s+\alpha)$, $\alpha \in \mathbb{C}_0^+$, then this admissible output operator equals $(\alpha I - A)^{-1}$.**

**Although in general $g(A)$ may be unbounded, we always have that $g(A)$ multiplied by the semigroup is a bounded operator for every (strictly) positive time instant. Furthermore, when there exists an admissible output operator $C$ such that $(C, A)$ is exactly observable, then $g(A)$ is bounded for all $g$'s with $g(-s) \in \mathcal{H}_\infty$.**

## Treatable *H*² Optimization for Infinite-Dimensional Systems
*(Invited Session)*

**Room 8**

***Organizers:*** *Yoshito Ohta, Leonid Mirkin*
***Chair:*** *Yoshito Ohta*

15.30 – 16.00

$H^2$ Performance on Multiple Preview Compensation and Internal State Setting
*Akira Kojima, Kazuki Yokoyama*

***Abstract***–**For a generalized $H^2$ preview control problem which includes the command of partial state setting, a design method of the preview control law is clarified. The result stated here covers $H^2$ multiple preview control problems and enables us to derive a compensation law for typical control systems. The feature of the preview compensation law is illustrated with a design example of preview servo-mechanism.**

16.00 – 16.30

On the $H^2$ Two-Side Model Matching Problem with Preview
*Maxim Kristalny, Leonid Mirkin*

***Abstract***–**The $H^2$ optimization problem with preview and asymptotic behavior constraints is considered in a general twoside model matching setting. The solution is obtained in terms of two constrained Sylvester equations, associated with asymptotic behavior, and stabilizing solutions of two algebraic Riccati equations. The Riccati equations do not depend on the preview length, yet are affected by asymptotic behavior constraints and are thus different from the standard $H^2$ Riccati equations arising in problems with no steady-state requirements or in one-side problems.**

16.30 – 17.00

Optimal Signal Reconstruction from a Series of Recurring Delayed Measurements
*Gjerrit Meinsma, Leonid Mirkin*

***Abstract***–**The modern sampled-data approach provides a general methodology for signal reconstruction. This paper discusses some implications for optimal signal reconstruction when a series of recurring measurements, some delayed, are available for the reconstruction.**

17.00 – 17.30

A Unified Solution of a Class of Continuous/Discrete-Time $H^2$ Control
*Kotaro Hashikura, Yoshito Ohta*

***Abstract***–**Explicit solutions for the $H^2$ control problem for systems with non-minimum phase property at the input such as input time-delay systems attract the interest of many researchers. The existing solution method cannot be seen as a natural generalization of closed-loop reduction of the finitedimensional standard $H^2$ problem. We give the method of solving two-block problems twice based on analysis of a statespace representation. The implication of the method is that the optimal controller of Smith form is obtained directly in both continuous- and discrete-time systems. The truncation operator introduced in the literature is utilized in solving the problem. We propose an alternative definition that is consistent for both continuous- and discrete-time cases. Furthermore, we show that the new definition is more appropriate to characterize the optimal control cost.**

## Systems on Graphs
*(Regular Session)*

**Room 9**

***Chair:*** *Giacomo Como*

15.30 – 16.00

Persistence of Disagreement in Social Networks
*Daron Acemoglu, Giacomo Como, Fabio Fagnani, Asuman Ozdaglar*

***Abstract–*****Disagreement among individuals in a society, even on central questions that have been debated for centuries, is the rule; agreement is the rare exception. How can disagreement of this sort persist for so long? Existing models of communication and learning, based on Bayesian or non-Bayesian updating mechanisms, typically lead to consensus provided that communication takes place over a strongly connected network.**

**We analyze a stochastic model of communication combined with the assumption that there are some "stubborn" agents in the economy who never change their opinions. We show that the presence of these stubborn agents leads to persistent disagreements among the rest of the society—because different individuals are within the "sphere of influence" of distinct stubborn agents and are influenced to varying degrees. Under general conditions, there is no convergence to a consensus. Instead, the expected cross-sectional distribution of beliefs in society converges (in distribution), and generally, the opinion of a single individual, and in fact that of the whole society, potentially fluctuates forever. This model provides a new approach to understanding persistent disagreements, and in the process, introduces new tools for the analysis of opinion formation and consensus models.**

16.00 – 16.30

Efficient Communication Infrastructures for Distributed Control and Decision Making in Networked Stochastic Systems
*John S. Baras, Pedram Hovareshti*

***Abstract–*****In networked systems, groups of agents achieve certain objectives via interaction at local levels in a decentralized manner. The performance of such systems is determined by the communication infrastructure of the network as well as the system dynamics. The interdependence of agents in a networked system is often modeled by graphs. We study the interdependence of communication and collaboration graphs in a networked system in the context of a coordination control and decision making problems. We model the decision on whether to cooperate or not in a group effort as a result of a series of two-person games between agents and their neighbors. The payoff of each agent is computed as the sum of the agent's payoffs from each of these games. Since coordination games have more than one equilibrium point, the problem is then which equilibrium point will the agents choose and whether they will settle on a Pareto-optimal equilibrium point. We consider a behavior learning algorithm and study its effect on the emergence of a collaboration graph. We also study the effect of the communication network topology on the convergence speed of the scheme.**

16.30 – 17.00

Spread of Epidemics in Time-Dependent Networks
*Vahid S. Bokharaie, Oliver Mason, Fabian Wirth*

***Abstract–*****We consider SIS models for the spread of epidemics. In particular we consider the so called nonhomogeneous case, in which the probability of infection and recovery are not uniform but depend on a neighborhood graph which describes the possibility of infection between individuals. In addition it is assumed, that infection, recovery probabilities as well as the interconnection structure may change with time. Using the concept of the joint spectral radius of a family of matrices conditions are provided that guarantee robust extinction of the epidemics.**

17.00 – 17.30

On Robust Stability of the Belief Propagation Algorithm for LDPC Decoding
*Björn S. Rüffer, Peter M. Dower, Christopher M. Kellett, Steven R. Weller*

***Abstract–*****The exact nonlinear loop gain of the belief propagation algorithm (BPA) in its log-likelihood ratio (LLR) formulation is computed. The nonlinear gains for regular lowdensity parity-check (LDPC) error correcting codes can be computed exactly using a simple formula. It is shown that in some neighborhood of the origin this gain is actually much smaller than the identity. Using a small-gain argument, this implies that the BPA is in fact locally input-to-state stable and produces bounded outputs for small-in-norm input LLR vectors. In a larger domain the algorithm produces at least bounded trajectories. Further it is shown that, as the block length increases, these regions exponentially shrink.**

17.30 – 18.00

The PABTEC Algorithm for Passivity-Preserving Model Reduction of Circuit Equations
*Tatjana Stykel, Timo Reis*

***Abstract–*****We present a passivity-preserving balanced truncation model reduction method for circuit equations (PABTEC). This method is based on balancing the solutions of the projected Lur'e equations and admit computable error bounds. We show how the topological structure of circuit equations can be exploited to reduce the computational complexity of the presented model reduction method.**

## Applications of Differential Geometry
*(Regular Session)*

**Room 10**

***Chair:*** *Markus Schöberl*

15.30 – 16.00

System Parametrization Using Affine Derivative Systems
*Markus Schöberl, Karl Rieger, Kurt Schlacher*

***Abstract–*****In this paper we discuss the constructive calculation of a flat system parametrization for nonlinear implicit control systems which are quasilinear in the derivative coordinates. The proposed scheme is based on the successive reduction of derivative variables and the elimination of non-derivative variables. A key challenge is the derivation of a procedure that maintains the quasi-linearity also in the elimination steps, since this is beneficial for the subsequent reductions. Two examples demonstrate the applicability of the suggested methods.**

16.00 – 16.30

Impulsive Transfer of Elliptical Orbits for Consensus of Two Spacecraft with Conservation of System Areal Velocity
*Kazunori Furusawa, Tomohisa Hayakawa*

***Abstract–*****A consensus control framework for two spacecraft traveling around the earth on elliptical orbits is developed. The control inputs are assumed to be impulsive and achieves a consensus state of the two spacecraft with control instants at most twice under the condition that the total angular momentum is conserved. We show an illustrative numerical example to demonstrate efficacy of the proposed approach.**

16.30 – 17.00

Integrability and Optimal Control
*Claudiu C. Remsing*

***Abstract*–This paper considers left-invariant control affine systems evolving on matrix Lie groups. Any left-invariant optimal control problem (with quadratic cost) can be lifted, via the celebrated Maximum Principle, to a Hamiltonian system on the dual of the Lie algebra of the underlying state space G. The (minus) Lie-Poisson structure on the dual space g* is used to describe the (normal) extremal curves. Complete integrability of (reduced) Hamiltonian dynamical systems is discussed briefly. Some observations concerning Casimir functions and the case of semisimple (matrix) Lie groups are made. As an application, a drift-free left-invariant optimal control problem on the rotation group SO (3) is investigated. The reduced Hamilton equations associated with an extremal curve are derived in a simple and elegant manner. Finally, these equations are explicitly integrated by Jacobi elliptic functions.**

17.00 – 17.30

Accessibility and Observability for a Class of First-Order PDE Systems with Boundary Control and Observation
*Karl Rieger, Kurt Schlacher*

***Abstract*–A group-theoretical approach is used to tackle both the problem of local accessibility and observability along a trajectory for a class of first-order PDE systems with boundary control and observation. Based on an intrinsic formulation including boundary terms (local) criteria are derived in form of equivalence problems, where existence and/or non-existence of (pointwise) transformation groups and their invariants is related to (non-)observability and/or (non-) accessibility of PDE systems, respectively. Examples demonstrate the theory and results.**

## Structured Non-Linear Systems
*(Regular Session)*

**Room 11**

***Chair:*** *László Gerencsér*

15.30 – 16.00

Change Detection for Hidden Markov Models
*László Gerencsér, Cecilia Prosdocimi*

***Abstract*–Hidden Markov Models (HMM-s) are widely used in a number of application areas. In this paper we consider the problem of detecting changes in the statistical pattern of a hidden Markov process. We adapt the so-called Hinkley-detector that was first introduced for independent observations. Assuming that the dynamics before and after the change is known, we are lead to the problem of analyzing the Hinkley-detector with an L-mixing input. It is shown that, under suitable technical conditions, the output process is also L- mixing. The result yields a rigorous upper bound for the falsealarm frequency. The limitations and potentials of the result will also be discussed.**

16.00 – 16.30

Three Dimensional Multi-Scale Modeling of Brain Tumor Progression
*Francisco Gamaliel Vital-Lopez, Costas D. Maranas, Antonios Armaou*

***Abstract*–We present a mathematical agent-based model that describes tumor progression as the outcome of the collective behavior of individual tumor cells, which is determined by capturing the interplay between the intracellular signaling pathways (e.g., MAPK pathway) and the temporal-spatial distribution of key biochemical cues (e.g., nutrients, growth factors). The distribution of nutrients depends on a vascular network mimicking the structure of the actual brain white matter. Computational bottlenecks associated with the large number of cells and the solution of PDEs in a 3-D domain are addressed by using an in situ adaptive tabulation (ISAT) technique and a multi-grid method, respectively. The model is used to simulate the early stages of tumor development, before the onset of tumor-induced angiogenesis.**

16.30 – 17.00

Global Analysis of Firing Maps
*Alexandre Mauroy, Julien M. Hendrickx, Alexandre Megretski, Rodolphe Sepulchre*

***Abstract*–In this paper, we study the behavior of pulsecoupled integrate-and-fire oscillators. Each oscillator is characterized by a state evolving between two threshold values. As the state reaches the upper threshold, it is reset to the lower threshold and emits a pulse which increments by a constant value the state of every other oscillator.**

**The behavior of the system is described by the so-called firing map: depending on the stability of the firing map, an important dichotomy characterizes the behavior of the oscillators (synchronization or clustering). The firing map is the composition of a linear map with a scalar nonlinearity.**

**After briefly discussing the case of the scalar firing map (corresponding to two oscillators), the stability analysis is extended to the general n-dimensional firing map (for n+1 oscillators). Different models are considered (leaky oscillators, quadratic oscillators,...), with a particular emphasis on the persistence of the dichotomy in higher dimensions.**

17.00 – 17.30

Intraoperative Prediction of Tumor Cell Concentration from Mass Spectrometry Imaging
*Vandana Mohan, Ivan Kolesov, Ferenc A. Jolesz, Nathalie Y.R. Agar, Allen R. Tannenbaum*

***Abstract*–This work is motivated by the problem of accurately locating tumor boundaries during brain tumor surgery. Currently, such boundary is typically localized using preoperative images and neuronavigation tools. While improved prognosis is associated with minimal residual tumor, an added challenge arises in surgical-decision making to completely excise the tumor and preserve eloquent cortex. We propose that an objective assessment of patterns of tumor cell concentration will help in performing this boundary location by identification of local minima of the tumor cell concentration as tumor boundaries. In this work, we aim to relate the mass spectrometry data - acquired from tissue sections by the Desorption Electrospray Ionization (DESI) approach - to histopathological scores of tumor cell concentration (as evaluated by the neuropathology expert), towards demonstrating that a system can be trained apriori on available tissue samples with known scores, and can be used intraoperatively as an integrated DESI probe to predict the score of the tissue under analysis. We apply the Relevance Vector Machine technique towards learning a ”model” that allows us to estimate the tumor cell concentration given the mass spectra. We quantify the performance of this model by testing the framework on real mass spectrometry data acquired from brain tumors (gliomas) of different grades and subtypes with promising results in prediction, and further motivate its intraoperative application.**

## Stochastic Control – 2
*(Invited Session)*

**Room 13**

***Organizers:*** *Bozenna Pasik-Duncan, Tyrone E. Duncan*
***Chair:*** *Tyrone E. Duncan*

15.30 – 16.00

Convergence Rates of Markov Chain Approximation Methods for Controlled Regime-Switching Diffusions with Stopping
*Qingshuo Song, George Yin*

***Abstract*–This work summarizes our recent work on rates of convergence of Markov chain approximation methods for controlled switching diffusions, in which both continuous dynamics and discrete events coexist. The discrete events are formulated by continuous-time Markov chains to delineate random environment and other random factors that cannot be represented by diffusion processes. The cost function is over an infinite horizon with stopping times and without discount. The paper demonstrates how to use a probabilistic approach for studying rates of convergence. Although there have been significant developments in the literature using PDE (partial differential equation) methods to approximate controlled diffusions, there appear to be yet any PDE results to date for rates of convergence of numerical solutions for controlled switching diffusions to the best of our knowledge. Moreover, in the literature, to prove the convergence using Markov chain approximation methods for control problems involving cost functions with stopping (even for uncontrolled diffusion without switching), an assumption was used to avoid the socalled tangency problem. By modifying the value function, we demonstrate that the anticipated tangency problem will not arise in the sense of convergence in probability and convergence in L1.**

16.00 – 16.30

Existence of Strict Optimal Controls for Long-Term Average Stochastic Control Problems
*Francois Dufour, Richard H. Stockbridge*

***Abstract*–Convexity conditions are identified under which optimal controls in the class of strict controls exist for a large class of stochastic processes under a long-term average criterion in the presence of hard and/or soft constraints. The result adapts a similar result obtained by Haussmann and Lepeltier (1990) for a controlled diffusion under a mixed optimalstopping/ finite-horizon/first-exit criterion. The approach taken in this paper is to utilize an equivalent linear programming formulation of the control problem. These results apply to controlled processes such as diffusions, Markov chains, simple Markov jump processes, diffusions with jumps, regimeswitching diffusions and solutions to Lévy stochastic differential equations.**

16.30 – 17.00

The Beneš-Problem and Related Problems Revisited
*Kurt L. Helmes, Richard H. Stockbridge*

***Abstract*–We show how the Beneš-Problem, i. e. the problem of how to choose a nonanticapting control process u whose absolute value is bounded by 1 such that the second moment at time T of the controlled diffusion process X with drift process u is as small as possible, can be solved by analyzing a special entry-and-exit problem. A characterization of the optimal strategy of general entry-and-exit problems can be phrased in terms of a finite-dimensional nonlinear optimization problem. This nonlinear optimization problem can be solved explicitly for the case of switching controls of Brownian motion with a quadratic cost function of the state. The explicit solution is an essential ingredient of a new proof of the Beneš-Problem as well as related problems.**

17.00 – 17.30

Calculus of Expected Present Value Operators and Comparative Statics in Real Option Theory
*Svetlana Boyarchenko, Sergei Levendorskii*

***Abstract*–The paper provides a general framework for study of impact of various policy interventions on investment decisions of firms in a regime-switching environment. The underlying uncertainty is modeled as a Markov-modulated Brownian motion with embedded jumps or more general process with i.i.d. increments. Not only characteristics and type of a process depend on a state but the riskless rate and profit flow as well. In each state, the profit flow is an arbitrary non-decreasing function of the underlying process, which allows for profit flows with caps and floors, different level of taxation at different levels of profits, etc. Different levels of the riskless rate can be used to model stochastic interest rates. The formulas for the value functions and investment thresholds in different states allow for comparative statics. As an example, we study how the investment thresholds, firm's values and output levels depend on the floor for the output price. We design an efficient numerical procedure for calculation of the investment thresholds and value functions and their derivatives of order 1. The procedure does not involve numerical integration, and the derivatives are calculated as accurately as the thresholds and value functions themselves.We use numerical examples to study the dependence of investment thresholds on the floor, transition rates and interest rate uncertainty.**

## Finite Geometry and Network Codes
*(Invited Session)*

**Room 14**

***Organizers:*** *Joachim Rosenthal, Marcus Greferath*
***Chair:*** *Joachim Rosenthal*

15.30 – 16.00

Two-Intersection Sets in Projective Hjelmslev Spaces
*Thomas Honold*

***Abstract*–A set $S$ of points in a finite incidence structure is said to be a two-intersection set if there are integers $a < b$ such that $S$ meets every block in either $a$ or $b$ points (and both $a$, $b$ actually occur as intersection numbers). For point-hyperplane designs of the classical geometries PG$(k, q)$ such sets have been studied extensively and related to other combinatorial objects (maximal arcs, two-weight codes, strongly-regular graphs, partial difference sets). In this paper two-intersection sets in the coordinate projective Hjelmslev geometries PHG$(k,R)$ over finite chain rings $R$ of length 2 are investigated along similar lines.**

16.00 – 16.30

Construction of Codes for Network Coding
*Andreas-Stephan Elsenhans, Axel Kohnert, Alfred Wassermann*

***Abstract*–Based on ideas of Kötter and Kschischang [6] we use constant dimension subspaces as codewords in a network. We show a connection to the theory of q-analogues of a combinatorial designs, which has been studied in [1] as a purely combinatorial object. For the construction of network codes we successfully modified methods (construction with prescribed automorphisms) originally developed for the q-analogues of a combinatorial designs. We then give a special case of that method which allows the construction of network codes with a very large ambient space and we also show how to decode such codes with a very small number of operations.**

16.30 – 17.00

Linear Codes from Projective Spaces
*Michel Lavrauw, Leo Storme, Geertrui van de Voorde*

***Abstract*— The finite projective space $\mathrm{PG}(n, q)$, $q = p^h$, $p$ prime, $h \geq 1$, is also investigated from a coding-theoretical point of view. The linear code $\mathrm{C}_{s,t}(n, q)$ of $s$-spaces and $t$-spaces in a projective space $\mathrm{PG}(n, q)$, $q = p^h$, $p$ prime, $h \geq 1$, is defined as the vector space spanned over $\mathbb{F}_p$ by the rows of the incidence matrix of $s$-spaces and $t$-spaces. This linear code can be investigated purely for its coding-theoretical importance, but the properties of this linear code are also of interest for the finite projective space $\mathrm{PG}(n, q)$ itself. Some of the best results on substructures of finite projective spaces $\mathrm{PG}(n, q)$ have been obtained by using their corresponding codes. Recently, there has been a new incentive on the study of the minimum distance of these linear codes and their duals. In this paper, we summarize what is currently known about the minimum distance and small weight codewords of these linear codes and their duals.**

17.00 – 17.30

On the Normality of (Non-Mixed and Mixed) Optimal Covering Codes
*Gerzson Kéri*

***Abstract*–According to the experiences, it is a known fact that some essential features of normal codes are quite different for binary and for non-binary codes. After giving some explanation concerning this observation by referring to an old conjecture with its partial proof, its possible extensions and restrictions, and by giving some counterexamples in Section 3, subsequently an interesting inequality between the minimum distance and covering radius of normal codes is expounded in Section 4, which provides a lucid explanation for the observed dissimilarity between the behavior of binary and non-binary codes.**

## Geometric Control Theory for Linear Systems–2
*(Mini-Course)*

**Room 15**

***Organizers:*** *Giovanni Marro, Fabio Morbidi, Lorenzo Ntogramatzidis, Domenico Prattichizzo*

15.30 – 17.30

Geometric Control Theory for Linear Systems
*Giovanni Marro, Fabio Morbidi, Lorenzo Ntogramatzidis, Domenico Prattichizzo*

# Friday, 9 July

## Plenary Lecture

**Room 1**

***Chair:*** *Jan H. van Schuppen*

09.00 – 10.00

From Qualitative to Quantitative Models of Gene Regulatory Networks in Bacteria
*Hidde de Jong*

## Distributed Parameter Systems III: Optimal Control
*(Invited Session)*

**Room 1**

***Organizers:*** *Birgit Jacob, Michael A. Demetriou, Miroslav Krstic, Kirsten Morris, Hans Zwart*
***Chair:*** *Hans Zwart*

10.30 – 11.00

Representation of Solutions of Riccati Equations for Well-Posed Systems
*Mark R. Opmeer, Orest V. Iftime*

***Abstract*–We give a representation of self-adjoint solutions of the control Riccati equation of a well-posed linear system. At this level of generality the appropriate Riccati equation is an integral Riccati equation. We assume that the Riccati equation has a strongly stabilizing and a strongly anti-stabilizing solution, and that the difference of these two solutions is coercive. We further assume that the uncontrolled dynamics are given by a strongly continuous group. Our representation is in terms of invariant subspaces of the stabilizing closed-loop semigroup.**

11.00 – 11.30

LQ-Optimal Control for a Class of Time-Varying Coupled PDEs-ODEs System
*Amir Alizadeh Moghadam, Ilyasse Aksikas, J. Fraser Forbes, Stevan Dubljevic*

***Abstract*–This contribution addresses the development of a Linear Quadratic Regulator (LQR) for a set of time-varying hyperbolic PDEs coupled with a set of time-varying ODEs through the boundary. The approach is based on an infinitedimensional Hilbert state-space realization of the system and operator Riccati equation (ORE). In order to solve the optimal control problem, the ORE is converted to a set of differential and algebraic matrix Riccati equations. The feedback gain can then be found by solving the resulting matrix Riccati equations. The control policy is applied to a system of continuous stirred tank reactor (CSTR) and a plug flow reactor (PFR) in series and the controller performance is evaluated by numerical simulation.**

11.30 – 12.00

Design of Optimal Deterministic Output Estimators for Distributed Parameter Systems
*Jochem Vissers, Siep Weiland*

***Abstract*–This paper considers the optimal $H_2$ estimation problem for infinite dimensional systems with finite dimensional outputs. It is shown that this problem is equivalent to a dual problem that allows an interpretation as a standard Linear Quadratic optimization problem for an infinite dimensional system. A solution to the latter problem is derived which, in turn solves the optimal estimator problem.**

12.00 – 12.30

Linear-Quadratic Differential Games Revisited
*Michel C. Delfour*

***Abstract*–This paper revisits the pioneering work of P. Bernhard [2] on two-person zero-sum linear quadratic differential games and generalize it to utility functions without positivity assumptions on the matrices acting on the state variable and to linear dynamics with bounded measurable data matrices. The paper specializes to state feedback via Lebesgue measurable affine closed loop strategies with possible non $L^2$- integrable singularities. It first deals with $L^2$-integrable closed loop strategies and then with the larger family of strategies that may have non $L^2$-integrable singularities.**

## Realization and Information
*(Regular Session)*

**Room 2**

***Chair:*** *Charalambos D. Charalambous*

10.30 – 11.00

Rate Distortion Function for a Class of Relative Entropy Sources
*Farzad Rezaei, Charalambos D. Charalambous, Photios A. Stavrou*

***Abstract*–This paper deals with rate distortion or source coding with fidelity criterion, in measure spaces, for a class of source distributions. The class of source distributions is described by a relative entropy constraint set between the true and a nominal distribution. The rate distortion problem for the class is thus formulated and solved using minimax strategies, which result in robust source coding with fidelity criterion. It is shown that minimax and maxmin strategies can be computed explicitly, and they are generalizations of the classical solution. Finally, for discrete memoryless uncertain sources, the rate distortion theorem is stated for the class omitting the derivations while the converse is derived.**

11.00 – 11.30

Stochastic Realization of Binary Exchangeable Processes
*Lorenzo Finesso, Cecilia Prosdocimi*

***Abstract*–A discrete time stochastic process is called exchangeable if its *n*-dimensional distributions are, for all *n*, invariant under permutation. By de Finetti theorem any exchangeable process is representable through a unique, generally infinite, mixture of i.i.d. processes. We formulate, as a stochastic realization problem, the question of characterizing the binary exchangeable processes which are finite mixtures of i.i.d. processes. The realizability conditions and an exact realization algorithm are given in terms of the Hankel matrix of the process. We establish a connection with the realization problem of deterministic positive linear systems of the relaxation type.**

11.30 – 12.00

Stochastic Input-Output Realization of Bilinear Systems
*György Terdik, József Bokor*

***Abstract*–A bilinear stochastic system given in state space form is studied when both the input and the output are measured. The Hankel matrix of the system is built up in terms of the Fliess-series representation of the process. The Fliess-coe¢ cients are calculated by the cumulants between the output and the polynomials of the input.**

12.00 – 12.30

Weakly Operator Harmonizable Processes in Complete Correlated Actions
*Dan Popovici*

***Abstract*–We prove that a stochastic process in a correlated action is weakly operator harmonizable (w.o.h.) if and only if it has a stationary dilation. We identify, by analogy with the stationary case, the shift operator of a w.o.h. process which is, in our context, a linear contraction. Other conditions which are equivalent to the notion of weak operator harmonizability follow the solution of an operator moment problem proposed by Z. Sebestyén and solved by Z. Sebestyén and D. Popovici. The main result of the paper extends, to the case of w.o.h. processes in complete correlated actions, the classical decomposition of H. Cramér.**

## Analysis of Physical Systems
*(Regular Session)*

**Room 3**

***Chair:*** *Hans Zwart*

10.30 – 11.00

Analysis of the Three Dimensional Heat Conduction in Nano- or Microscale
*Hanif Heidari, Hans Zwart, Alaeddin Malek*

***Abstract*–The Dual-Phase-Lagging (DPL) equation is formulated as an abstract differential equation. In the absence of a heat source term the DPL equation with homogeneous boundary conditions generates a contraction semigroup. The exact expression of the semigroup is achieved. It is proved that the associated eigenfunctions form a Riesz basis. The stability of semigroup is proved. Moreover, it is also shown that the spectrum of DPL equation contains an interval. This implies that the infinitesimal generator associated to the DPL equation is not a Riesz spectral operator. Therefore, the known test for approximate controllability cannot be used. Several controllability properties are investigated.**

11.00 – 11.30

Well-Posedness, Regularity and Exact Controllability for the Problem of Transmission of the Schrödinger Equation
*Salah-Eddine Rebiai*

***Abstract*— In this paper, we shall study the system of transmission of the Schrödinger equation with Dirichlet control and colocated observation. Using the multiplier method, we show that the system is well-posed with input and ouput space $U = L^2(\Gamma)$ and state space $X = H^{-1}(\Omega)$. The regularity of the system is also established and the feedthrough operator is found to be zero. Finally, the exact controllability of the open-loop system is obtained by proving the observability inequality of the dual system.**

11.30 – 12.00

Hamiltonian Evolution Equations of Inductionless Magnetohydrodynamics
*Andreas Siuka, Markus Schöberl, Kurt Schlacher*

***Abstract*–The objective of this contribution is to find a coordinate independent Hamiltonian representation of the governing equations of inductionless Magnetohydrodynamics, where we are interested in analysing the relevant energy flows in a purely geometric fashion also taking dissipative effects into account. We especially treat the boundary conditions in an extraordinary manner and we define control inputs which may act on the system boundary. Finally, the Port-Controlled Hamiltonian system representation, well-known in the lumped parameter case, is also reflected in the infinite dimensional case which is crucial particularly with regard to control theoretic aspects.**

12.00 – 12.30

Instantaneous Control of the Linear Wave Equation

*Nils Altmüller, Lars Grüne, Karl Worthmann*

***Abstract***–**We are concerned with the one dimensional linear wave equation with Dirichlet boundary condition and Neumann boundary control. It has been shown numerically that this hyperbolic partial differential equation can be stabilized by instantaneous control, i.e. model predictive control with the shortest feasible prediction and optimization horizon. Our contribution is the complete theoretical analysis.**

12.30 – 13.00

Hybrid Modeling, Control and Estimation in ABS Applications Based on In-Wheel Electric Motors

*Ricardo de Castro, João de Sousa, Rui Esteves Araújo, Fernando Pereira, Diamantino Freitas*

***Abstract***–**The problems of tire slip control and peak friction estimation for Anti-lock Braking Systems are formulated and solved in the framework of hybrid control techniques. The hybrid systems model of the vehicle dynamics arises from approximating the nonlinear behavior of the tire-road friction coefficient with a Piecewise Linear Function (PLF). The problem of tyre slip control is formulated as an invariance problem. The invariance control problem is solved with the help of a simple hysteretic controller which takes advantage of the fast torque response from the in-wheel electric motor. The controller's properties, such as necessary conditions to ensure invariance, robustness to disturbances, convergence and limit cycle period are analyzed in detail. The problem of the estimating the peak friction for the tire-road interface is solved using properties of the limit cycles arising in the hybrid model. Monitoring the duty cycle, imposed by hysteretic controller, was found to be sufficient to extract information regarding the conditions of adhesion in the road. The controller and estimator were evaluated under variable grip levels, in a vehicle dynamics simulation software, obtaining a good performance for both the tire slip regulation and for the peak friction estimationd.**

## Behavioral Systems and Control Theory

*(Invited Session)*

**Room 4**

***Organizer:*** *Paolo Rapisarda*
***Chair:*** *Paolo Rapisarda*

10.30 – 11.00

A Polynomial Approach to the Realization of *J*-Lossless Behaviours

*Shodhan Rao, Paolo Rapisarda, Lewis Moody*

***Abstract***–**In this paper, a class of behaviours known as J-lossless behaviours is introduced, where J is a symmetric twovariable polynomial matrix. For a certain J, it is shown that the resulting set of J-lossless behaviours are SISO behaviours such that for each of such behaviours, there exists a quadratic differential form which is positive for nonzero trajectories of the behaviour and whose derivative is equal to the product of the input variable and the derivative of the output variable. Earlier, Van der Schaft and Oeloff had considered a specific form of realization for such behaviours that plays an important role in their model reduction procedure. In our paper, we give a method of computation of a state space realization from a transfer function of such a behaviour in the same form as considered by Van der Schaft and Oeloff, using polynomial algebraic methods. Apart from being useful in enlarging the scope of the model reduction procedure of Van der Schaft and Oeloff, we show that our method of realization also has application in the synthesis of lossless mechanical systems with given transfer functions using springs and masses.**

11.00 – 11.30

Pseudorational Behaviors and Bezoutians

*Yutaka Yamamoto, Jan C. Willems, Masaki Ogura*

***Abstract***–**Behavioral system theory has been successful in providing a viewpoint that does not depend on a priori notions of inputs/outputs. While there are some attempts to extend this theory to infinite-dimensional systems, for example, delay systems, the overall picture seems to remain still incomplete.**

**The first author has studied a class of infinite-dimensional systems called pseudorational. This class allows a compact fractional representation for systems having bounded-time memory. It is particularly appropriate for extending the behavioral framework to infinite-dimensional context.**

**We have recently studied several attempts to extend this framework to a behavioral context. Among them are characterizations of behavioral controllability, particularly involving a coprimeness condition over an algebra of distributions, and some stability tests involving Lyapunov functions derived from Bézoutians.**

**This article gives a brief overview of pseudorational transfer functions, controllability issues and related criteria, path integrals, and finally the connection with Lyapunov functions derived from Bézoutians.**

11.30 – 12.00

Tracking and Regulation in the Behavioral Framework

*Shaik Fiaz, Kiyotsugu Takaba, Harry Trentelman*

***Abstract***–**This paper considers the problem of tracking and regulation for the class of linear differential systems in the behavioral framework. Given a plant, together with an exosystem generating the disturbances and the reference signals, the problem of tracking and regulation is to find a controller such that the plant variable tracks the reference signal regardless of the disturbance acting on the system. A controller which achieves this design objective is called a regulator for the plant with respect to the exosystem. In this paper we formulate the tracking and regulation problem in the behavioral framework, with control as interconnection. We obtain necessary and sufficient conditions for the existence of a controller which acts like a regulator for the plant with respect to the exosystem. The problem formulation and its resolution are completely representation free, and specified only in terms of the plant and the exosystem dynamics.**

12.00 – 12.30

Ports and Terminals

*Jan C. Willems*

***Abstract***–**We examine what is meant by the power and the energy which a physical system exchanges with its environment. The systems which we consider interact through terminals, as wires for electrical circuits, and pins for mechanical devices. Associated with each terminal, there are variables through which the system interacts with its environment. For circuits, these variables are current and potential, and for (one-dimensional) mechanical systems, position and force. Systems are interconnected by sharing variables at the interconnected terminals.**

**We define a port as a set of terminals that satisfy certain conditions, which we call the port-Kirchhoff laws. For ports, and only for ports, we define the power and the energy which flows into a system. Since a port involves more than one terminal, power and energy are not `local', but involve `action**

at a distance'. Moreover, we cannot speak about the power and the energy flow along any set of terminals.

We discuss the nature of ports for electrical and mechanical systems, and derive an expression for energy that is not frame dependent. We prove that a connected RLC circuit forms a 1-port. This implies that in open systems energy rarely flows between subsystems along the interconnected interface.

For mechanical systems the definition of a port implies that springs, dampers, and inerters form port, but a mass does not. This leads to the problem how one should define the motion energy of a group of moving masses. We derive an expression for the motion energy, which is different from the classical expression of kinetic energy. Our formula implies that motion energy is not an extensive quantity.

## Shadows of Multidimensionality: Multidimensional Systems with Applications to 1-D Systems – 1

*(Invited Session)*

**Room 6**

***Organizers:*** *Joseph A. Ball, Victor Vinnikov*
***Chair:*** *Victor Vinnikov*

10.30 – 11.00

Structured Noncommutative Multidimensional Linear Systems and Scale-Recursive Modeling
*Tanit Malakorn, Joseph A. Ball*

*Abstract*–Recently, the multiscale signal and image processing community has recognized that a suitable model for multiresolution processes is a model with time-like variable indexed by the nodes on a homogeneous tree with different depths in the tree corresponding to different spatial scales associated with the signal or image. It turns out that these system models are close relatives of the Structured Noncommutative Multidimensional Linear Systems (SNMLSs) introduced by Ball-Groenewald- Malakorn [5], but with system operators dependent on the node of the tree at which the state update occurs. This provides engineering motivation for the introduction of a “parametervarying” version of SNMLS.

11.00 – 11.30

Controllability of Autonomous Behaviors and Livšic Overdetemined Systems as 2D Behaviors with Pure Autonomy Degree One
*Grant Boquet, Joseph A. Ball*

*Abstract*–In [8] discrete time Livšic systems are related to 2D behaviors with autonomy degree one. A necessary component for transitioning from a behavior to a Livšic system is a “controllability theory” for autonomous behaviors. It turns out that controllability for behaviors is a special case of the presented *j*-controllability. First we present a brisk overview of the ingredients that go into (algebraic) $D_r$-controllability and (trajectory) *j*-controllability. We conclude with results demonstrating Livšic controllability implies 1-controllability and then $D_r$-controllability by a series of reduction steps.

11.30 – 12.00

The H$^\infty$-Problem in Multidimensional Control Theory: State-Space versus Frequency-Domain Formulation
*Joseph A. Ball, Sanne ter Horst*

*Abstract*–Two by now standard approaches to the classical H$^\infty$-problem go either through co-prime factorizations reducing it to a metric constrained interpolation problem, or via state-space realizations of the given data functions and admissible controllers leading to a description of the solutions in terms of solutions of coupled linear matrix inequalities (LMIs). The connection between the interpolation and the state-space approach relies on the seamless equivalence of frequency-domain and state-space representation. In the cases of multivariable interpolation and systems with structured uncertainty similar reductions and solution criteria exist (after some compromises with respect to the solution criterions). The connection between the results however is not clear due to the failure of the state-space similarity theorem and Kalman decomposition in these settings, and as a result research on the two topics has diverted. In this talk, which is based on the paper [1], we discuss these developments and make some explicit connections.

12.00 – 12.30

Linear State Space Theory in the White Noise Space Setting
*Daniel Alpay, David Levanony, Ariel Pinhas*

*Abstract*–We study state space equations within the white noise space setting. A commutative ring of power series in a countable number of variables plays an important role. Transfer functions are rational functions with coefficients in this commutative ring, and are characterized in a number of ways. A major feature in our approach is the observation that key characteristics of a linear, time invariant, stochastic system are determined by the corresponding characteristics associated with the deterministic part of the system, namely its average behavior.

## Systems on Graphs – Consensus

*(Regular Session)*

**Room 7**

***Chair:*** *Enrico Lovisari*

10.30 – 11.00

A Resistance-Based Approach to Performance Analysis of the Consensus Algorithm
*Enrico Lovisari, Federica Garin, Sandro Zampieri*

*Abstract*–We study the well–known linear consensus algorithm by means of a LQ-type performance cost. We want to understand how the communication topology influences this algorithm. In order to do this, we recall the analogy between Markov Chains and electrical resistive networks. By exploiting this analogy, we are able to rewrite the performance cost as the average effective resistance on a suitable network. We use this result to show that if the communication graph fulfills some local properties, then its behavior can be approximated with that of a suitable grid, over which the behavior of the cost is known.

11.00 – 11.30

Notes on the Deficiency One Theorem: Single Linkage Class
*Balázs Boros*

*Abstract*–The Deficiency One Theorem tells us about certain chemical reaction systems that they cannot admit multiple interior equilibria. The theorem was proven by Feinberg. In this paper we provide a relatively short proof of that theorem for the special case of one linkage class. We also extend that result by giving an equivalent condition to the fact that the set of interior equilibria is nonempty for a chemical reaction system with one linkage class considered in the Deficiency One Theorem.

11.30 – 12.00

Optimal Finite-Time Distributed Linear Averaging
*Qing Hui*

***Abstract*–A new optimal finite-time distributed linear averaging (OFTDLA) problem is presented in this paper. This problem is motivated from the distributed averaging problem which arises in the context of distributed algorithms in computer science and coordination of groups of autonomous agents in engineering. The aim of the OFTDLA problem is to compute the average of the initial values in finite-time steps at nodes of a graph through an optimal distributed algorithm in which the nodes in the graph can only communicate with their neighbors. Optimality is given by a minimization problem of a quadratic cost functional under finite-time horizon. We show that this problem has a very close relationship with the notion of semistability. By developing new necessary and sufficient conditions for semistability of discrete-time linear systems, we convert the original OFTDLA problem into two equivalent optimization problems. One of them is a convex optimization problem and can be solved by using semidefinite programming methods.**

12.00 – 12.30

Dilatability of Linear Cellular Automata
*Adriana Popovici, Dan Popovici*

***Abstract*–We introduce a notion of dilatability between two LCAs and relate it with the notion of (power) dilatability between the corresponding global transition functions. We prove that a partial isometric LCA can be dilated to a quantum LCA which is reversible. In particular, any isometric LCA *A* can be dilated to a quantum LCA B such that the global rule of B extends the global rule of *A*.**

## Model Reduction
*(Regular Session)*

**Room 8**

***Chair:*** *André Schneider*

10.30 – 11.00

Balanced Truncation Model Order Reduction for LTI Systems with many Inputs or Outputs
*Peter Benner, André Schneider*

***Abstract*–We discuss balanced truncation (BT) based methods for model order reduction (MOR) of linear time invariant (LTI) systems with many input or many output terminals. Applying BT methods makes it necessary to balance the system, which is equivalent to finding the controllability and observability Gramian of the system in a special diagonal form. The Cholesky factors of these Gramians are efficiently computable as solutions of dual Lyapunov equations for systems with only few inputs and outputs. After a brief introduction and a short recollection of basic knowledge of BT, we show a method to get the Gramians' factors also for systems with many inputs and outputs with the help of the Gauss-Kronrod quadrature formula. We show some numerical results using this quadrature rule and explain how to get the BT reduced order model out of these results.**

11.00 – 11.30

Balanced Truncation for Linear Interconnected Systems: the State Feedback Case
*Kenji Fujimoto, Sayaka Ono, Yoshikazu Hayakawa*

***Abstract*–Model order reduction is an important tool in control systems theory. In particular, it is useful for controller design since the dimension of the controller becomes very high when we use advanced control theory. Balanced truncation is one of the most useful model order reduction methods. In general, however, the stability of the feedback system is not maintained when the order of the controller is reduced by balanced truncation. This paper proposes a novel method of state feedback controller reduction by which we can preserve the stability of the resulting reduced order state feedback system. A numerical example demonstrates the effectiveness of the proposed method.**

11.30 – 12.00

Numerical Algorithm for Structured Low Rank Approximation Problem
*Swanand R. Khare, Harish K. Pillai, Madhu N. Belur*

***Abstract*–In this paper we discuss an important problem of Structured Low Rank Approximation (SLRA) of linearly structured matrices. This is a very important problem having many applications like computation of approximate GCD, model order reduction to name a few. In this paper we formulate SLRA problem as an unconstrained optimization problem on a smooth matrix manifold. We use Armijo line search algorithm on the matrix manifold to compute the nearest SLRA of the given matrix.**

12.00 – 12.30

Finite Time System Operator and Balancing for Model Reduction and Decoupling
*Erik I. Verriest*

***Abstract*–In this paper we explore the operator mapping a finite time segment of the input signal to the output over the same interval. The properties of this operator are compared to the finite time Hankel operator that was useful in sliding interval balancing (SIB). Potential applications for model reduction and decoupling of systems are discussed.**

12.30 – 13.00

Model Order Reduction of Nonlinear Circuits
*Andreas Steinbrecher*

***Abstract*–In this talk we develop a model order reduction for the model equations of nonlinear circuits with a small number of nonlinear elements. The presented model reduction technique is based on the decoupling of the linear and nonlinear subcircuits of the electrical circuit in a suitable way. Afterwards, a model reduction of the remained linear part will be performed using passivity-preserving balanced truncation followed by an adequate recoupling of the unchanged nonlinear subcircuit and the reduced linear subcircuit to obtain a nonlinear reducedorder model. The efficency and applicability of the proposed model reduction approach is demonstrated on a numerical examples.**

## Networked Control – 1
*(Regular Session)*

**Room 9**

***Chair:*** *Karl Mårtensson*

10.30 – 11.00

Sub-Optimality Bound on a Gradient Method for Iterative Distributed Control Synthesis
*Karl Mårtensson, Anders Rantzer*

***Abstract*–A previous paper introduced an online gradient method to iteratively update local controllers for improved performance. In this paper we modify that method to get an offline method for distributed control synthesis. The complexity of the method is linear in the number of neighbors to each agent.**

Since the controllers are constructed to be distributed and the method is an iterative scheme, the controllers will always be sub-optimal compared to a centralized controller. We describe a method to calculate bounds of the sub-optimality of the controllers, using the same variables that take part in the update scheme.

11.00 – 11.30

The Logarithmic Quantiser is Not Optimal for LQ Control
*Jean-Charles Delvenne*

***Abstract***—**We seek to stabilise a scalar linear system through a finite-capacity communication channel, while minimising a quadratic cost. We show that the logarithmic quantiser strategy is not optimal for the quadratic cost in the limit of low capacities.**

11.30 – 12.00

Distributed Inequality Constrained Kalman Smoother
*Simone Del Favero, Gianluigi Pillonetto, Bradley M. Bell*

***Abstract***—**This paper, which is the sequel of [1], considers smoothing of Gauss-Markov linear systems via distributed optimization. As an application we consider the distributed estimation problem over sensor networks and assume that each node has access to noisy measurements of different but correlated states. Then, the aim is to reconstruct the overall state sequence in a cooperative way, by taking advantage of all the data collected by the network.**

**In this paper, the convergence analysis in [1] is deepened, pointing out the importance in the algorithm design, of finding the right trade off between parallelism and convergence rate. Moreover an extension of the algorithm to the case of state sequence subject to inequality constraints is also provided. In particular, we show that the same algorithmic architecture and communication protocol used in the unconstrained case can be exploited in the constrained scenario. Hence, the network can efficiently include in the estimation process relevant a priori information on the state, such as nonnegativity. Numerical experiments regarding the distributed reconstruction of a function via spline regression is used to test the new approach.**

12.00 – 12.30

MIMO Encoder and Decoder Design for Signal Estimation
*Erik Johannesson, Andrey Ghulchak, Anders Rantzer, Bo Bernhardsson*

***Abstract***—**We study the joint design of optimal linear MIMO encoders and decoders for filtering and transmission of a vectorvalued signal over parallel Gaussian channels subject to a realtime constraint. The objective is to minimize the sum of the estimation error variances at the receiving end. The design problem is nonconvex, but it is shown that a global optimum can be found by solving a related two-stage problem. The first stage consists of a mixed norm minimization problem, where the 2-norm corresponds to the error variance in a corresponding Wiener-Kolmogorov filtering problem and the 1-norm is induced by the channel noise. The second stage consists of a matrix spectral factorization.**

## Analytical Methods
*(Regular Session)*

**Room 10**

***Chair:*** *Tamás Kalmár-Nagy*

10.30 – 11.00

Random Walk on a Rooted, Directed Husimi Cactus
*Tamás Kalmár-Nagy*

***Abstract***—**The objective of this paper is to further explore the connection between the random Fibonacci series and a random walk on the so-called triangular Husimi cactus. Various statistical properties of this random walk are computed.**

11.00 – 11.30

Scalable Decentralized Control and the Davis-Wielandt Shell
*Ioannis Lestas*

***Abstract***—**We consider a large scale network comprised of heterogeneous dynamical agents. We derive scalable stability certificates that involve the input/output properties of individual subsystems and corresponding properties of the interconnection matrix. The stability conditions presented are based on the Davis-Wielandt shell, a higher dimensional version of the numerical range, which allows to relax normality or symmetry assumptions on the interconnection matrix. The conditions derived include small gain and passivity approaches as special cases, and generalize many results within the areas of consensus protocols and Internet congestion control.**

11.30 – 12.00

Characterization of Shift Invariant Subspace of Matrix-valued Hardy Space
*Yohei Kuroiwa*

***Abstract***—**The characterization of the shift invariant subspace of the matrix-valued Hardy space is given. It is a matrix-valued generalization of the Beurling-Lax theorem. The Beurling-Lax theorem provides the one-sided representation of a shift invariant subspace by a unique inner function. Our characterization of the shift invariant subspace of the matrixvalued Hardy space is given by a two-sided representation of a shift invariant space by inner and co-inner functions.**

## Quantum Systems
*(Regular Session)*

**Room 11**

***Chair:*** *Francesca Albertini*

10.30 – 11.00

Methods of Control Theory for the Analysis of Quantum Walks on Graphs
*Francesca Albertini, Domenico D'Alessandro*

***Abstract***—**The goal of this paper is to summarize recent results on the analysis of quantum walks on graphs. These systems are used in quantum information theory as protocols to design quantum algorithms. By taking into account that some model variables can be changed with time, quantum walks can be looked at as control systems and several questions can be posed in control theoretic terms. In particular the set of states that can be reached for these systems can be characterized via controllability analysis. After setting up the model, the main results of the paper characterize the controllability of quantum walks both in algebraic and in combinatorial terms. Several examples are also discussed.**

11.00 – 11.30

Parameter Estimation of Quantum Processes Using Convex Optimization
*Gábor Balló, Attila Magyar, Katalin M. Hangos*

**Abstract–A convex optimization based method is proposed for quantum process tomography, in the case of known channel model structure, but unknown channel parameters. The main idea is to select an affine parametrization of the Choi matrix as a set of optimization variables, and formulate a semidefinite programming problem with a least squares objective function. Possible convex relations between the optimization variables are also taken into account to improve the estimation.**

**Simulation case studies show, that the proposed method can significantly increase the accuracy of the parameter estimation, if the channel model structure is known. Beside the convex part, the determination of the channel parameters from the optimization variables is a nonconvex step in general. In the case of Pauli channels however, the method reduces to a purely convex optimization problem, allowing to obtain a globally optimal solution.**

11.30 – 12.00

Martingale Approach in Quantum State Estimation Using Indirect Measurements
*László Ruppert, Katalin M. Hangos*

**Abstract–The aim of this work is to propose mathematically well grounded statistical methods for state estimation in the indirect measurement settings by using martingale theory, and to compare their efficiency to the usual direct approaches. The measurement scheme considered is the simplest possible discrete time case, where both the unknown and the measurement quantum systems are quantum bits. The repeated measurements performed on the measurement subsystem of the composite system enables us to construct an estimator for the initial state of the unknown system. An initial state relative method of detecting a stopping time is proposed where the final states are defined using a given distance from the unknown initial state. A simple estimator is proposed and used as an excellent initial point to build more complex and better estimation methods. The efficiency of the proposed procedure is investigated both analytically and experimentally using simulation in different settings of parameters. The possible generalizations of the proposed estimation methods are also outlined.**

12.00 – 12.30

The Energy Minimization Problem for Two-Level Dissipative Quantum Systems
*Dominique Sugny, Bernard Bonnard*

**Abstract–The objective of this article is to present developments of geometric optimal control to analyze the energy minimization problem of dissipative two-level quantum systems whose dynamics is governed by Kossakowski-Lindblad equations. This analysis completed by numerical simulations based on adapted algorithms allows a computation of the optimal control law whose robustness with respect to initial conditions and dissipative parameters is also detailed.**

12.30 – 13.00

On a Canonical QR Decomposition and Feedback Control of Discrete-Time Quantum Dynamics
*Francesco Ticozzi, Saverio Bolognani*

**Abstract–We study feedback-controlled, discrete-time quantum Markovian dynamics focusing on pure-state stabilization problem. Assuming that the system is unitarily controllable, and accessible via a given quantum measurement, we explicitly construct a choice of control actions conditioned on the measurement outcome that globally stabilizes the target state for the averaged dynamics. A key step in deriving this result is the definition of a canonical QR decomposition for complex matrices.**

## Applications in Medicine
*(Regular Session)*

**Room 12**

***Chair:*** *Andras Balogh*

10.30 – 11.00

Bifurcation Control in an Infectious Disease Model
*Andras Balogh, Roberto Castillo, Noel Cavazos Jr.*

**Abstract–In this work we examine a basic mathematical model describing the spread of a class of infectious diseases. A system of four integral equations represents the SEIRS model, where individuals go through stages of being susceptible (S), exposed (E), infective (I), and recovered (R) for constant periods of time intervals. Transcritical bifurcation of steady state solutions can be observed in the system as the basic reproduction number increases. The eigenvalue analysis of the linearized equations provides local stability results. A stable numerical algorithm is developed that demonstrate the theoretical results.**

11.00 – 11.30

Identifiability Analysis of an Epidemiological PDE Model
*Antoine Perasso, Béatrice Laroche, Suzanne Touzeau*

**Abstract–We investigate the parameter identifiability problem for a SIR system of nonlinear integro-partial differential equations of transport type, representing the spread of a disease with a long infectious but undetectable period in an animal population. After obtaining the expression of the model inputoutput (IO) relationships, we give sufficient conditions on the boundary conditions of the system that guarantee the parameter identifiability on a finite time horizon. We finally illustrate our findings with numerical simulations.**

11.30 – 12.00

Unification of Accelerated and Proportional Hazard Rate Models and Application for Data of the Hungarian National Cancer Registry
*Lídia Rejtő*

**Abstract–In the literature of multifactorial survival analysis, individual survival curves are described eventually with a single parameter deeming all survival curves to be parallel ([1], [3], [6], [9]). Previously described theories are not able to produce all form of survival curves we may meet; in contrast, we propose a novel method which can handle cases, for example, with constant hazard rate and rapidly decreasing ones simultaneously. Using our methods we estimated survival chances of 189,026 tumor cases, recognized between 2001 and 2005 in Hungary and recorded in NCR.**

## Control for Markov and Nonlinear Markov Processes

*(Invited Session)*

**Room 13**

***Organizers:*** *William M. McEneaney, Vassili N. Kolokoltsov*
***Chair:*** *Vassili N. Kolokoltsov*

10.30 – 11.00

Nonlinear Markov Games
*Vassili N. Kolokoltsov*

***Abstract–*****A program of the analysis of a new class of stochastic games is put forward, which I call nonlinear Markov games, as they arise as a (competitive) controlled version of nonlinear Markov processes (an emerging field of intensive research, see e.g. [2], [5], [6]). This class of games can model a variety of situation for economics and epidemics, statistical physics, and pursuit - evasion processes. The discussion below will be presented i more detail in the author's monograph [1].**

11.00 – 11.30

Stochastic Adaptive Nash Certainty Equivalence Control: Self-Identification Case
*Arman C. Kizilkale, Peter E. Caines*

***Abstract–*****For noncooperative games the Nash Certainty Equivalence (NCE), or Mean Field (MF) methodology developed in previous work provides decentralized strategies which asymptotically yield Nash equilibria. The NCE (MF) control laws use only the local information of each agent on its own state evolution and knowledge of its own dynamical parameters, while the behaviour of the mass is precomputable from knowledge of the distribution of dynamical parameters throughout the mass population.**

**Relaxing the a priori information condition introduces the methods of parameter estimation and stochastic adaptive control (SAC) into MF control theory. In particular one may consider incrementally the problems where the agents must estimate: (i) its own dynamical parameters, (ii) the distribution of the population's dynamical parameters [1], and (iii) the distribution of the population's cost function parameters [2]. In this paper we treat the first problem.**

**Each agent estimates its own dynamical parameters via the recursive weighted least squares (RWLS) algorithm. Under reasonable conditions on the population dynamical parameter distribution, we establish: (i) the strong consistency of the selfparameter estimates; and that (ii) all agent systems are long run average $L^2$ stable; (iii) the set of controls yields a (strong) $\epsilon$-Nash equilibrium for all $\epsilon$; and (iv) in the population limit the long run average cost obtained is equal to the non-adaptive long run average cost.**

11.30 – 12.00

Stopping Problems of Markov Processes with Discontinuous Functionals
*Lukasz Stettner*

***Abstract–*****The paper summarizes recent results on optimal stopping of Feller Markov processes with time or space discontinuous functionals. We characterize value functions and their potential discontinuity points for various cost functionals: finite time horizon, first exit from an open set horizon and infinite horizon. Formulae for optimal or $\epsilon$ optimal stopping times are also given.**

12.00 – 12.30

Observation Process Control in Support of Stochastic Tasking Operations
*William M. McEneaney, Ali Oran*

***Abstract–*****We consider a problem of observation control, specifically a problem where one chooses which aspects of the state to observe at each time-step. The state takes values in a finite set, and the conditional probability updates by Bayes' rule. The payoff for observation takes the form of a finite maximum of linear functions of the final observationconditioned probability distribution, and so is a convex function of the distribution. However, the goal is maximization, not minimization. Through use of the max-plus distributive property, we are able to use a max-plus curse-of-dimensionalityfree computational method for solution of the control problem. Complexity attenuation of the algorithm is addressed.**

## Algebraic Systems Theory, Behaviors, and Codes: Design, Analysis, and Decoding of Convolutional Codes

*(Invited Session)*

**Room 14**

***Organizers:*** *Heide Glüsing-Lürssen, Eva Zerz*
***Chair:*** *Heide Glüsing-Lürssen*

10.30 – 11.00

Decoding of a Class of Convolutional Codes
*Heide Glüsing-Lürssen, Uwe Helmke, José Ignacio Iglesias Curto*

***Abstract–*****A general decoding algorithm for convolutional codes will be exposed. Under certain conditions this algorithm will allow to correct a high number of errors in an interval of fixed length. We will show that a class of Cyclic Convolutional Codes is particularly well suited for this iterative algorithm in two aspects: first, it satisfies the conditions so that the error correcting capacities of the algorithm are optimized; secondly, the computations needed at each iteration are feasible. Consequently, the application of the algorithm to this class of codes results in an efficient decoding method.**

11.00 – 11.30

On the Determination of an Input-State-Output Realization of a Secure McEliece-Like Cryptosystem Based on Convolutional Codes
*Joan Josep Climent, Victoria Herranz, Carmen Perea, Virtudes Tomás*

***Abstract–*****In this paper we present a public key cryptosystem based on the McEliece scheme, but using a convolutional code, instead of a block code. Firstly we present some conditions about the convolutional code $C$ to construct the public key cryptosystem and then, starting with the parity check matrix $H$ of a good block code, we find an input-state-output representation of $C$ such that the controllability matrix of $C$ is $H^t$. This cryptosystem is constructed so that any user can encrypt a message by introducing the largest number of possible errors.**

11.30 – 12.00

Reverse-Maximum Distance Profile Convolutional Codes over the Erasure Channel
*Virtudes Tomás, Joachim Rosenthal, Roxana Smarandache*

***Abstract–*****The loss of transmitted packets over an erasure channel, such as the Internet, can generate delay of the received information due to retransmission, and this can have**

adverse effects in real-time applications. Error forward correction is a technique used to avoid this delay. Until now mainly block codes have been used for this purpose and convolutional codes have been much less studied. In this paper we study in detail the use of convolutional codes over this channel and we show that the complexity of decoding is polynomial. We see how maximum distance profile (MDP) convolutional codes can deal with situations which are not possible for a maximum distance separable (MDS) block code and we introduce a new concept: reverse-MDP convolutional codes. Reverse-MDP codes double the potential of MDP convolutional codes since they behave as MDP codes in a forward and a backward sense. Due to this fact, we propose this new kind of codes as very good candidates to improve the decoding process. In addition, we provide a particular construction for reverse-MDP convolutional codes.

12.00 – 12.30

Column Distances for 2D-Convolutional Codes
*Diego Napp Avelli, Carmen Perea, Raquel Pinto*

*Abstract*–In this work we introduce the concept of column distance for delay-free two dimensional (2D) finite support convolutional codes. We present its principal properties and an upper and lower bound for the column distances.

## Differential Geometric Methods for Computational Engineering Applications – 1
*(Invited Session)*

**Room 15**

***Organizers:*** *Knut Hüper, Christian Lageman*
***Chair:*** *Knut Hüper*

10.30 – 11.00

Adaptive Filtering for Estimation of a Low-Rank Positive Semidefinite Matrix
*Silvère Bonnabel, Gilles Meyer, Rodolphe Sepulchre*

*Abstract*–In this paper, we adopt a geometric viewpoint to tackle the problem of estimating a linear model whose parameter is a fixed-rank positive semidefinite matrix. We consider two gradient descent flows associated to two distinct Riemannian quotient geometries that underlie this set of matrices. The resulting algorithms are non-linear and can be viewed as a generalization of Least Mean Squares that instrically constrain the parameter within the manifold search space. Such algorithms designed for low-rank matrices find applications in high-dimensional distance learning problems for classification or clustering.

11.00 – 11.30

Intrinsic Newton's Method on Oblique Manifolds for Overdetermined Blind Source Separation
*Martin Kleinsteuber, Hao Shen*

*Abstract*–This paper studies the problem of Overdetermined Blind Source Separation (OdBSS), a challenging problem in signal processing. It aims to recover desired sources from outnumbered observations without knowing either the source distributions or the mixing process. It is well-known that performance of standard BSS algorithms, which usually utilize a whitening step as a pre-process to reduce the dimensionality of observations, might be seriously limited due to its blind trust on the data covariance matrix. In this paper, we develop and compare two locally quadratic OdBSS algorithms that forgo the dimensionality reduction step. In particular, our algorithms solve a problem of simultaneous diagonalization of a set of symmetric matrices. By exploiting the appropriate underlying manifold, namely the so-called oblique manifold, intrinsic Newton's method is developed to optimize two popular cost functions for the simultaneous diagonalization of symmetric matrices: the off-norm function and the log-likelihood function. Performance of the proposed algorithms is investigated and compared by several numerical experiments.

11.30 – 12.00

A Geometric Revisit to the Trace Quotient Problem
*Hao Shen, Klaus Diepold, Knut Hüper*

*Abstract*–This paper studies the problem of trace quotient, or trace ratio maximization, which has enormous applications in computer vision, pattern recognition and machine learning. We provide a geometric revisit to the problem in the framework of optimization on smooth manifolds. The set of critical points of the trace quotient is analyzed. Local quadratic convergence properties of the so-called Iterative Trace Ratio (ITR) scheme, which recently became an attractive solver to the problem, is studied. Based on this result, different from a popular realization of ITR, which requires to solve a symmetric eigenvalue problem at each iteration, we propose a simple, efficient algorithm, which employs only one step of the parallel Rayleigh quotient iteration at each iteration. An numerical experiment demonstrates the local convergence properties of ITR.

12.00 – 12.30

Local Minima of the Best Low Multilinear Rank Approximation of Tensors
*Mariya Ishteva, Pierre-Antoine Absil, Sabine van Huffel, Lieven de Lathauwer*

*Abstract*–Higher-order tensors are generalizations of vectors and matrices to third- or even higher-order arrays of numbers. We consider a generalization of column and row rank of a matrix to tensors, called multilinear rank. Given a higher-order tensor, we are looking for another tensor, as close as possible to the original one and with multilinear rank bounded by prespecified numbers. In this paper, we give an overview of recent results pertaining the associated cost function. It can have a number of local minima, which need to be interpreted carefully. Convergence to the global minimum cannot be guaranteed with the existing algorithms. We discuss the conclusions that we have drawn from extensive simulations and point out some hidden problems that might occur in real applications.

## Semiplenary Lecture

**Room 1**

***Chair:*** *Tyrone E. Duncan*

14.00 – 15.00

Nonlinear Filtering and Systems Theory
*Ramon van Handel*

*Abstract*–The fundamental connection between the stability of linear filtering and linear systems theory was already remarked in Kalman's seminal 1960 paper. Unfortunately, the linear theory relies heavily on the investigation of the explicit Kalman filtering equations, and sheds little light on the behavior of nonlinear filters. Nonetheless, it is possible to establish surprisingly general connections between the stability of nonlinear filters and nonlinear counterparts of basic concepts in linear systems theory: stability, observability, detectability. The proofs of these results are probabilistic in nature and provide significant insight into the mechanisms that give rise to filter stability. The aim of this paper is to review these recent results and to discuss some of their applications.

## Semiplenary Lecture

**Room 14**

***Chair:*** *Clyde F. Martin*

14.00 – 15.00

Controllability of Networked Systems
*Magnus Egerstedt*

*Abstract*—**In this paper we investigate the controllability properties associated with networked control systems whose information exchange takes place over a static communication network. The control signal is assumed to be injected into the network at a given input node and its influence is propagated through the network through a nearest-neighbor interaction rule employed to ensure network cohesion. In particular, the problem of driving a collection of mobile robots to a given target destination is studied, and conditions are given for this to be possible, based on tools from algebraic graph theory. The main result is a necessary and sufficient condition for an interaction topology to be controllable, given in terms of the network's external, equitable partitions.**

## Semiplenary Lecture

**Room 15**

***Chair:*** *Doreen Thomas*

14.00 – 15.00

Quantum Linear Systems Theory
*Ian R. Petersen*

*Abstract*—**This paper surveys some recent results on the theory of quantum linear systems and presents them within a unified framework. Quantum linear systems are a class of systems whose dynamics, which are described by the laws of quantum mechanics, take the specific form of a set of linear quantum stochastic differential equations (QSDEs). Such systems commonly arise in the area of quantum optics and related disciplines. Systems whose dynamics can be described or approximated by linear QSDEs include interconnections of optical cavities, beam-spitters, phase-shifters, optical parametric amplifiers, optical squeezers, and cavity quantum electrodynamic systems. With advances in quantum technology, the feedback control of such quantum systems is generating new challenges in the field of control theory. Potential applications of such quantum feedback control systems include quantum computing, quantum error correction, quantum communications, gravity wave detection, metrology, atom lasers, and superconducting quantum circuits.**

**A recently emerging approach to the feedback control of quantum linear systems involves the use of a controller which itself is a quantum linear system. This approach to quantum feedback control, referred to as coherent quantum feedback control, has the advantage that it does not destroy quantum information, is fast, and has the potential for efficient implementation. This paper discusses recent results concerning the synthesis of H-infinity optimal controllers for linear quantum systems in the coherent control case. An important issue which arises both in the modelling of linear quantum systems and in the synthesis of linear coherent quantum controllers is the issue of physical realizability. This issue relates to the property of whether a given set of QSDEs corresponds to a physical quantum system satisfying the laws of quantum mechanics. The paper will cover recent results relating the question of physical realizability to notions occuring in linear systems theory such as lossless bounded real systems and dual J-J unitary systems.**

## Distributed Parameter Systems IV: Computational Issues

*(Invited Session)*

**Room 1**

***Organizers:*** *Birgit Jacob, Michael A. Demetriou, Miroslav Krstic, Kirsten Morris, Hans Zwart*
***Chair:*** *Hans Zwart*

15.30 – 16.00

Numerical Approximation of Exact Controls for Vibrating Systems
*Nicolae Cîndea, Sorin Micu, Marius Tucsnak*

*Abstract*—**The numerical study of the exact controls of infinite dimensional systems started in the 90's with a series of papers of Glowinski and Lions (see [3, 4]) where algorithms to determine the minimal $L^2$-norm exact controls (sometimes called HUM controls) are provided. Several abnormalities presented in these works stand at the origin of a large number of articles in which a great variety of numerical methods are presented and analyzed (see, for instance, [5], [2] and the references therein). However, except the recent work [1], where the approximation of the HUM controls for the one dimensional wave equation is considered, to our knowledge, there are no results on the rate of convergence of the approximative controls.**

**Our main theoretical result gives the rate of convergence of our approximations to an exact control. Moreover, to illustrate the efficiency of this approach, we apply it to several systems governed by PDE's and we describe the associated numerical simulations. Our methodology combines Russell's "stabilizability implies controllability" principle with error estimates for finite element type approximations of the considered infinite dimensional systems.**

16.00 – 16.30

Robust Output Controller Design Based on Adaptive Model Reduction for Parabolic PDE Systems
*Sivakumar Pitchaiah, Antonios Armaou*

*Abstract*—**The problem of designing robust feedback controller for spatially distributed processes, described by parabolic PDE systems, is addressed by designing robust output feedback controllers using adaptive proper orthogonal decomposition methodology (APOD). Initially, an ensemble of eigenfunctions is constructed based on a relatively small data ensemble which is then recursively updated as additional process data becomes available periodically. These eigenfunctions are then utilized in deriving a reduced order model (ROM) of the PDE system by employing the Galerin's method. The obtained ROM is further utilized for the synthesis of robust feedback controllers via geometric techniques. Under the assumption that the number of measurements sensors is equal to the number of modes of the ROM, we obtain the the estimates for the states of the ROM using a static observer. Utilizing these estimated states in the robust controllers leads to robust output feedback controllers that guarantee boundedness of the state along with uncertainty attenuation in the infinite-dimensional system. As new data from the closed-loop process becomes available we update the ROM (and hence the robust controller) by employing APOD. The theoretic results are successfully applied to a representative example of dissipative PDEs with nonlinearities and uncertainty.**

16.30 – 17.00

Overview of Consensus Filters for Distributed Parameter Systems Utilizing Sensor Networks
*Michael A. Demetriou*

***Abstract*–This work summarizes two types of consensus filters for a class of distributed parameter systems: consensus and adaptive-consensus filters. Furthermore, it proposes a metric for comparing the disagreement among the spatially local filters. It is assumed that a sensor network consists of groups of sensors, each of which provides a number of state measurements from sensing devices that are not necessarily identical to each other and which only transmit their information to their own sensor group. A metric for examining the disagreement of the local filters, as extended from the finite dimensional case, essentially yields a deterministic analog of the standard deviation of the spatially local filter errors. The disagreement metric is examined for both consensus and adaptive consensus filters. The measure of disagreement is subsequently shown to be linked to the state estimation errors thereby simplifying the performance analysis to simply that of stability of the estimating scheme.**

17.00 – 17.30

Sensor Network Design for Inverse Problems
*Dariusz Uciński*

***Abstract*–The aim of this work is to expose an optimal node activation algorithm in sensor networks whose measurements are supposed to be used to estimate unknown parameters of the underlying process model in the form of a partial differential equation. By partitioning the observation horizon into a finite number of consecutive intervals, the problem is set up to select nodes which will be active over each interval while the others will remain dormant such that a general convex design criterion defined on the Fisher information matrix associated with the estimated parameters is minimized. The search for the optimal solution is performed using the branch-and-bound method in which an efficient technique is employed to produce a lower bound to the minimum of the objective function.**

## New Paradigms for Control

*(Regular Session)*

**Room 2**

***Chair:*** *Fritz Colonius*

15.30 – 16.00

Minimal Data Rates and Invariance Entropy
*Fritz Colonius*

***Abstract*–For compact locally controlled invariant subsets of the state space, minimal data rates for achieving invariance are characterized by the invariance entropy. In particular, for linear control systems with bounded control range, locally invariant sets are constructed and the associated minimal data rates are computed.**

16.00 – 16.30

Fast Controls and Their Calculation
*Alexander Daryin, Yulia Minaeva*

***Abstract*–New technologies, such as control in quantum systems, may require that the control would act on a very small time horizon. Another requirement is that the control should be designed in a closed-loop form. A possible response to this demand is the use of fast controls [1]. They are introduced as bounded approximations of generalized impulse controls (belonging to the class of higher-order distributions).**

16.30 – 17.00

Optimal Event-Triggered Control under Costly Observations
*Adam Molin, Sandra Hirche*

***Abstract*–Digital control design is commonly constrained to time-triggered control systems with equidistant sampling intervals. The emergence of more and more complex and distributed systems urges the development of advanced triggering schemes that utilize computational and communication resources efficiently. This paper considers a linear stochastic continuous-time setting, where the design objective is to find an event-triggered controller that optimally meets the trade-off between control performance and resource utilization. This is reflected by imposing a cost penalty on updating the controller by current observations that is added to a quadratic control cost. It is shown that the underlying optimization problem results in an event-triggered controller, where the controller is updated, when the estimation error of the controller exceeds an apriori determined threshold. The controller design is related to linear quadratic Gaussian regulation and to optimal stopping time problems. Contrary to the initial problem, these can be solved by standard methods of stochastic optimal control. Numerical examples underline the effectiveness compared to optimal time-triggered controllers.**

## Electrical Circuits

*(Regular Session)*

**Room 3**

***Chair:*** *Luigi Fortuna*

15.30 – 16.00

Chaos Control in Inductor-Based Chaotic Oscillators
*Arturo Buscarino, Luigi Fortuna, Mattia Frasca, Gregorio Sciuto*

***Abstract*–In this work a new chaos control technique for inductor-based chaotic oscillators is introduced. The technique consists of coupling the original circuit with a further passive control circuitry, made of a coupled inductor and a variable resistor. The dynamics of the oscillator can be controlled by varying a single external control parameter, i.e. the resistor value. The technique has been applied to two case studies, leading to circuits exhibiting a rich dynamics, including stable limit cycles of different periods, bistability, and new regions of chaos.**

16.00 – 16.30

A Reduced Model of Reflectometry for Wired Electric Networks
*Mohamed Oumri, Qinghua Zhang, Michel Sorine*

***Abstract*–Reflectometry is a technology frequently used for the diagnosis of failures in wired electric networks. For the purpose of developing advanced diagnosis methods, a reduced mathematical model of reflectometry is proposed in this paper. Based on the telegrapher's equations and on the Kirchhoff's laws, this model leads to a simple algorithm for the computation of frequency domain reflection coefficients from the characteristic parameters of the transmission lines and their connections in a star-shaped or a tree-shaped network. This algorithm implemented in a digital computer can easily simulate networks composed of different and inhomogeneous transmission lines. Comparisons between simulated reflection coefficients and real reflectometry measurements confirm the validity of the proposed model.**

## Computing
*(Regular Session)*

**Room 4**

***Chair:*** *Pierre-Antoine Absil*

15.30 – 16.00

An Efficient BFGS Algorithm for Riemannian Optimization
*Chunhong Qi, Kyle A. Gallivan, Pierre-Antoine Absil*

***Abstract***–**In this paper, we present a convergence result for Riemannian line-search methods that ensures superlinear convergence. We also present a theory of building vector transports on submanifolds of $R^n$ and discuss its use to assess convergence conditions and computational efficiency of the resulting Riemannian optimization algorithms. We illustrate performance and check predictions of our theory using a version of a Riemannian BFGS algorithm we proposed earlier.**

16.00 – 16.30

Properties of a Parameterized Model Reduction Method
*Aivar Sootla*

***Abstract***–**In this contribution a recently proposed model reduction method for a class of linear time-invariant (LTI) parameterized models is investigated. The method is based on matching of the frequency response samples using the semidefinite programming methods. The main focus of this contribution is the properties of the obtained approximations. Among those properties is stability of individual LTI systems, continuity with respect to parameters, error bounds on approximation quality.**

16.30 – 17.00

A Notion of Approximation for Systems Over Finite Alphabets
*Danielle C. Tarraf*

***Abstract***–**We consider the problem of approximating plants with discrete sensors and actuators (termed 'systems over finite alphabets') by deterministic finite memory systems for the purpose of certified-by-design controller synthesis. We propose a new, control-oriented notion of input/output approximation for these systems, that builds on ideas from robust control theory and behavioral systems theory. We conclude with a brief discussion of the key features of the proposed notion of approximation relative to those of two existing notions of finite state approximation and abstraction.**

## Shadows of Multidimensionality: Multidimensional Systems with Applications to 1-D Systems – 2
*(Invited Session)*

**Room 6**

***Organizers:*** *Joseph A. Ball, Victor Vinnikov*
***Chair:*** *Joseph A. Ball*

15.30 – 16.00

Multievolution Scattering Systems and the Multivariable Schur Class
*Dmitry S. Kaliuzhnyi-Verbovetskyi*

***Abstract***–**We show using the multievolution scattering systems formalism how to obtain the decompositions of multivariable Schur-class functions which are analogous, to a certain extent, to Agler's decompositions of Schur–Agler-class functions. In particular, this gives a new class of d-tuples of commuting strict contractions on a Hilbert space which satisfy the multivariable von Neumann inequality.**

16.00 – 16.30

Overdetermined Systems on Lie Groups and Their Transfer Functions
*Eli Shamovich*

***Abstract*—In this paper we define the notion of an overdetermined systems on a Lie group $\mathfrak{G}$ and its associated Lie algebra operator vessel. We define the transfer functions of such systems which turn out to be the joint characteristic functions of the associated vessel. We study the properties of the transfer functions via restriction to one-parameter subgroups of $\mathfrak{G}$. A formula connecting the values of the transfer function with the characteristic function of the infinitesimal generator of the group will be given and an example will be provided for $\mathfrak{G}$ the $ax+b$-group.**

16.30 – 17.00

On the Class *RSI* of Rational Schur Functions Intertwining Solutions of Linear Differential Equations
*Daniel Alpay, Andrey Melnikov, Victor Vinnikov*

***Abstract*—In this paper we extend and solve in the class of functions $\mathcal{RSI}$ [Li], [MV1], [MVc], [M], [M2] mentioned in the title, a number of problems originally set for the class $\mathcal{RS}$ of rational functions contractive in the open right-half plane, and unitary on the imaginary line with respect to some preassigned self-adjoint matrix [BLi], [L]. The problems we consider include the Schur algorithm [A], [AD], [AMV], [FK], the partial realization problem and the Nevanlinna-Pick interpolation problem [N], [P], [BGR], [Dy].**

**The arguments rely on the study of moments of such functions around infinity and one-to-one correspondence between elements in a given subclass of $\mathcal{RSI}$ and elements in a subclass of $\mathcal{RS}$. Another important tool in the arguments is a new result pertaining to the classical tangential Schur algorithm.**

17.00 – 17.30

On Ranks of Noncommutative Polynomials
*Victor Vinnikov*

***Abstract***–**We consider the minimum of the rank of a given noncommutative polynomial in d noncommuting indeterminates when evaluated on d-tuples of nxn matrices. It is conjectured that the minimum of the normalized rank, that is of the rank divided by n, tends to 0 as n tends to infinity; an even stronger conjecture is that the minimum of the rank stabilizes for sufficiently large n. These conjectures appeared in free noncommutative algebra (the study of two sided principal ideals in the ring of noncommutative polynomials). They are important for free noncommutative algebraic geometry that has emerged recently as a powerful tool when dealing with dimension independent problems in systems and control. Of course rank minimization problems are in general ubiquitous in control and optimization.**

## Consensus and Games
*(Regular Session)*

**Room 7**

***Chair:*** *Xiaoming Hu*

15.30 – 16.00

Optimal Output Consensus Control and Outlier Detection
*Johan Thunberg, Xiaoming Hu*

***Abstract***–**In this paper we study the output consensus problem for systems of agents with linear continuous time invariant dynamics, and derive control laws that minimize a conical combination of the energies of the agents control signals, while only using local information. We show that the optimal control requires the connectivity graph to be complete**

and in general requires measurements of the state errors. We identify the cases where the optimal control is only based on output errors, and show that in the infinite time horizon case, the optimal control can always be expressed as a dynamic control that is only based on the output errors. We also give a Lemma for the position of the equilibrium point for a large class of agent dynamics. As a second part of this paper we consider the problem of outlier detection, in which an agent wants to deduce if an other agent is using the consensus controller, or if it is an outlier that uses a different controller. We introduce the outlier detection equation.

16.00 – 16.30

Distributed Consensus Under Limited Information
*Haopeng Zhang, Qing Hui*

***Abstract*–Consensus for networked control systems has a significant application in civil and military applications, while most of the literature focus on the research of consensus for the networked control system with ideal measurements. However, in practice, those assumptions can not be guaranteed properly. Due to the communication link and information storage memory limitations, quantization consensus is more reasonable for the networked control system since the quantized values are less ideal than the perfectly measured values and much more easier to access and transmit in practice. In this paper, we present a novel quantized consensus protocol for the networked control system and prove that near-consensus is achieved under this protocol. To obtain the exact-consensus for the quantized system, a distributed consensus algorithm is further investigated. Finally, the Matlab simulations are provided to verify our theoretical results.**

16.30 – 17.00

Emergence of Lévy Flights in Distributed Consensus Systems
*Jing Wang, Nicola Elia*

***Abstract*–In this paper, we consider a multi-agent model which generates a collective super-diffusion behavior. Although such complex behaviors are ubiquitous in many natural and human-made systems, discovering mechanisms of their emergence is mostly an open research area. Our model is motivated to solve consensus problem under limitations on information exchange including link failures and additive noise. We use orthogonal decomposition approach to analyze the system and establish several equivalent necessary and sufficient conditions for Mean Square (MS) stability of part of this system. We show that the emergence of the super-diffusion behavior is introduced by the loss of MS stability and prove it to be Lévy flights for a special system. This work is the first, to the best of our knowledge, to establish the intimate relationship between propagation of uncertainties in networks, the MS stability robustness and the emergence of Lévy flights, which may have far reaching consequence on the understanding and engineering of complex systems.**

17.00 – 17.30

Anti-Palindromic Pencil Formulation for Open-Loop Stackelberg Strategy in Discrete-Time
*Marc Jungers, Cristian Oară*

***Abstract*–The Stackelberg strategy offers, in gametheoretic framework an adapted concept to obtain equilibrium for hierarchical games. For linear-quadratic games, Stackelberg strategy with open-loop information structure leads to solve non-symmetric Riccati equations, by assumming the invertibility of some weighting matrices. This paper provides an antipalindromic pencil approach to formulate it. Thus it allows to relaxe invertibility assumptions and furthermore to take advantage of the recent literature of numerical methods for palindromic pencils.**

## Robust Convex Control
*(Regular Session)*

**Room 8**

***Chair:*** *Debraj Chakraborty*

15.30 – 16.00

Bang-Bang Solutions to the Open Loop Maximal Time Problem
*Debraj Chakraborty*

***Abstract*–The problem of maximizing the duration of open loop operation of a perturbed linear time invariant system, while keeping performance errors within bound, is considered. It was shown in an earlier article that the optimal control for this problem is purely bang-bang if an associated switching function is non-zero almost everywhere. Sufficient conditions are derived in this article to guarantee this situation.**

16.00 – 16.30

Robust Stabilization with Real Parametric Uncertainty via Linear Programming
*Svetlana Iantchenko, Andrey Ghulchak*

***Abstract*–A numerical method is proposed for optimal robust control synthesis. A dual interpretation of the problem is derived. In the special case, when uncertainty parameter is real-valued, it is shown that the dual problem becomes essentially finite dimensional in the space of variables (semiinfinite convex programming). It makes possible to efficiently obtain a numerical solution of the dual problem and to construct the optimal robustly stabilizing controller via the alignment principle. In order to illustrate the method, several examples on the robust stabilization with real uncertainties are solved (both analytically and numerically).**

16.30 – 17.00

Treatment of Systems Nonlinearities by a Multiplier Method
*Éva Gyurkovics, Tibor Takács*

***Abstract*–This paper investigates the conditions under which an abstract matrix multiplier method can be applied to determine guaranteeing cost controls for systems containing nonlinear/ uncertain elements via linear matrix inequalities (LMIs). Quadratically constrained uncertainties and nonlinearities are considered which comprehend the cases of norm-bounded, positive-real and sector-bounded uncertainties/nonlinearities. Both the discrete-time and the continuous-time cases are discussed. Necessary and sufficient conditions are formulated in case of unstructured uncertainty. The conditions are sufficient in the structured case. The cost guaranteeing controls can be determined by solving LMIs. The proposed method provides a guideline to treat system nonlinearities, if the system dynamics can be formulated as considered in the paper by an approriate choice of system parameters.**

17.00 – 17.30

Gain-Scheduled $H_2$ Filter Synthesis via Polynomially Parameter-Dependent Lyapunov Functions with Inexact Scheduling Parameters
*Masayuki Sato*

***Abstract*–This paper addresses the design problem of Gain-Scheduled (GS) $H_2$ filters for Linear Parameter-Varying (LPV) systems under the condition that only inexactly measured scheduling parameters are available. The state-space matrices of the LPV systems are supposed to be polynomially parameter dependent and those of filters which are to be designed are supposed to be rationally parameter dependent. The uncertainties in the measured scheduling parameters are**

supposed to lie in a priori defined convex set. Using structured polynomially Parameter-Dependent Lyapunov Functions (PDLFs), we give a design method of GS $H_2$ filters, which are robust against the uncertainties in the measured scheduling parameters, in terms of parametrically affine Linear Matrix Inequalities (LMIs). Our proposed method includes robust filter design as a special case. A numerical example demonstrates the effectiveness of our method.

## Networked Control – 2

*(Regular Session)*

**Room 9**

***Chair:*** *Shivkumar V. Iyer*

15.30 – 16.00

Application of Graph Theory in Stability Analysis of Meshed Microgrids

*Shivkumar V. Iyer, Madhu N. Belur, Mukul C. Chandorkar*

***Abstract***–**This paper studies microgrids where loads are supplied by parallel connected inverters controlled by decentralized active power/voltage frequency and reactive power/voltage magnitude droop control laws. The implementation of droop control laws for sharing of power between inverters has been known to present stability problems particularly for large values of active power/voltage frequency droop control gains. Stability analysis of the microgrid requires a mathematical formulation of the interaction between the inverters due to their droop control laws. However, a simple and elegant mathematical model resulting in a conclusive proof of stability has been found to be lacking in reported literature. In this paper, a state dynamical model has been derived by combining active power flow equations with the active power/voltage frequency droop control laws. Using an analogy between the model matrix and connected graphs, a proof of stability of the microgrid has been stated as a theorem. The paper further examines the limitations of the proof and the difference between the results of the proof and reported practical results.**

16.00 – 16.30

Power-Aware Sensor Coverage: an Optimal Control Approach

*Patrick Martin, Rosalba Galvan-Guerra, Magnus Egerstedt, Vadim Azhmyakov*

***Abstract***–**Sensor networks primarily have two competing objectives: they must sense as much as possible, yet last as long as possible when deployed. In this paper, we approach this problem using optimal control. We describe a model that relates each sensor's "footprint" to their power consumption and use this model to derive optimal control laws that maintain the area coverage for a specified operational lifetime. This optimal control approach is then deployed onto different sensor networks and evaluated for its ability to maintain coverage during their desired lifetime.**

16.30 – 17.00

Distributed Electrical Power Distribution Using Evolutionary Variational Inequalities

*Abubakr Muhammad*

***Abstract***–**In this paper, we study a projected dynamical system PDS suggested by Nagurney et al. for the solution of an electrical power distribution problem. We study the PDS from the point of view of the topology of the grid control network. In particular, we first cast this PDS in a graph theoretic (or topological) form by using the strategy outlined by the author in a previous paper. Next, by studying the critical points of this PDS for various topologies, we compare the solution of the global optimization problem with that of the optima reached under limited network information. In this way, we are able to incorporate the effect of network control topology into the computational aspects of the optimization problem. We also characterize the topological properties of command and control structures that result in global optima, without the need to use the full information of the grid.**

## Robust Control

*(Regular Session)*

**Room 10**

***Chair:*** *Didier Henrion*

15.30 – 16.00

Convex Inner Approximations of Nonconvex Semialgebraic Sets Applied to Fixed-Order Controller Design

*Didier Henrion, Christophe Louembet*

***Abstract***–**We describe an elementary algorithm to build convex inner approximations of nonconvex sets. Both input and output sets are basic semialgebraic sets given as lists of defining multivariate polynomials. Even though no optimality guarantees can be given (e.g. in terms of volume maximization for bounded sets), the algorithm is designed to preserve convex boundaries as much as possible, while removing regions with concave boundaries. In particular, the algorithm leaves invariant a given convex set. The algorithm is based on Gloptipoly 3, a public-domain Matlab package solving nonconvex polynomial optimization problems with the help of convex semidefinite programming (optimization over linear matrix inequalities, or LMIs). We illustrate how the algorithm can be used to design fixed-order controllers for linear systems, following a polynomial approach.**

16.00 – 16.30

Stability Analysis of Discrete-Time Systems with Time-Varying Delays via Integral Quadratic Constraints

*Chung-Yao Kao*

***Abstract***–**This manuscript presents certain $l_2$-gain properties of and the integral quadratic constraint characterizations derived from these properties for the discrete-time time-varying operator. These IQC characterizations are crucial for the IQC analysis to be applied to study robustness of discretetime systems in the presence of time-varying delays. One new contribution of this manuscript is to utilize the information of the variation of the delay parameter to derive less conservative IQCs. The effectiveness of the proposed IQC analysis is verified by numerical experiments, the results of which are compared with those recently published in the literature.**

16.30 – 17.00

Robust Stability Analysis of Inverse LQ Regulator for Linear Systems with Input Delay

*Takao Fujii, Osamu Kaneko*

***Abstract***–**We analyze the robust stability of Inverse LQ regulators for single-input linear systems with uncertain input delay. Unlike the usual LQ regulator, the Inverse LQ regulator has a gain tuning pa-rameter that can be chosen freely to some extent without losing its LQ optimality. Utilizing this freedom we seek the range of tuning parameter that ensures the robust stability against the uncertain de-lay time, as well as the robust stability condition of the Inverse LQ regulator for some gain tuning parameter. The result is based on the quadratic stabilization problem.**

17.00 – 17.30

Periodically Time-Varying Controller Synthesis for Multiobjective H2/H$_\infty$ Control of Discrete-Time Systems and Analysis of Achievable Performance

*Yoshio Ebihara, Jun Yamaguchi, Tomomichi Hagiwara*

***Abstract*–In this paper, we propose a linear periodically time-varying (LPTV) controller synthesis approach for the multiobjective H2/H$_\infty$ control problem of discrete-time linear time-invariant (LTI) systems. By artificially regarding the LTI plant as N-periodic and applying the discrete-time system lifting, we first derive an SDP for the synthesis of suboptimal multiobjective LPTV controllers. Furthermore, we show that we can reduce the conservatism and improve the control performance gradually by simply increasing the controller period. On the other hand, in the latter part of the paper, we propose another SDP for the computation of a lower bound of the control performance that is achievable via LPTV controllers of any period and order. Similarly to the LPTV controller synthesis, the SDP is derived based on the liftingbased treatment of the LTI plant, and it is shown that we can improve the lower bound gradually by increasing the fictitious period N. We validate all of these theoretical results through an illustrative example.**

## Quantum Systems and Control

*(Regular Session)*

**Room 11**

***Chair:*** *Francesco Ticozzi*

15.30 – 16.00

Schrödinger Bridges for Discrete-Time, Classical and Quantum Markovian Evolutions

*Michele Pavon, Francesco Ticozzi*

***Abstract*–The theory of Schrödinger bridges for diffusion processes is extended to discrete-time Markov chains, and to some problems for quantum discrete-time processes. Taking into account the past-future lack of symmetry of the discrete-time setting, results bear a striking resemblance to the classical ones. In particular, the solution of the path space maximum entropy problems is always obtained from the prior model by means of a suitable multiplicative functional transformation.**

16.00 – 16.30

A Unified Approach to Controllability of Closed and Open Quantum Systems

*Indra Kurniawan, Gunther Dirr, Uwe Helmke*

***Abstract*— Based on Lie-algebraic methods from nonlinear control theory, we present a unified approach to control problems of finite dimensional closed and open quantum systems. In particular, we provide a simplified treatment of different controllability notions for closed quantum systems as well as new accessibility results for open quantum systems described by the Lindblad-Kossakowski master equation. To derive controllability and accessibility results, we exploit known results on the classification of all Lie groups which act transitively on Grassmann manifolds, and respectively, on $\mathbb{R}^d \setminus \{0\}$. For the special case of open quantum systems of coupled spin-$\frac{1}{2}$ particles, we obtain a remarkably simple characterization of accessibility.**

16.30 – 17.00

Symmetry in Quantum System Theory of Multi-Qubit Systems

*Robert Zeier, Uwe Sander, Thomas Schulte-Herbrüggen*

***Abstract*— Controllability and observability of multi-spin systems under various symmetry constraints are investigated complementing recent work [1]. Conversely, the absence of symmetry implies irreducibility and provides a convenient necessary condition for full controllability. Though much easier to assess than the well-established Lie-algebra rank condition, this is not sufficient unless in an $n$-qubit system with connected coupling topology the candidate dynamic simple Lie algebra can be identified uniquely as the full unitary algebra $\mathfrak{su}(2^n)$. Based on a complete list of irreducible simple subalgebras of the $\mathfrak{su}(N)$ in question, easy tests solving homogeneous linear equations filter irreducible unitary representations of other candidate algebras of classical type as well as of exceptional types. — Finally, having identified the dynamic system algebra, many observability issues can be treated immediately.**

17.00 – 17.30

Quantum Stochastic Stability and Weak-* Convergence of System Observables

*Ram Somaraju, Ian R. Petersen*

***Abstract*–The evolution of open quantum systems can be described using quantum stochastic differential equations (QSDEs). The solution of QSDEs leads to a one parameter semigroup of completely positive operators with which one can associate a minimal quantum Markov dilation. In this paper, we use a Lyapunov type theorem to prove asymptotic stability in the weak-* operator norm for such minimal Markov dilations provided some assumptions are satisfied. This theorem uses the fact that the unit ball in the space of bounded operators on a Banach space is weak-* compact.**

## Systems Biology

*(Regular Session)*

**Room 12**

***Chair:*** *Krisztina Kiss*

15.30 – 16.00

Prey and Polyphagous Predator Species with Diffusion

*Zsuzsanna Barta, Krisztina Kiss*

***Abstract*–This paper deals with a ratio–dependent polyphagous predator–prey system taking into account the spatial movement of the species. We will investigate under what conditions Turing stability or instability occurs in higher dimensions.**

16.00 – 16.30

Robust Dynamical Network Reconstruction

*Ye Yuan, Guy-Bart Stan, Sean Warnick, Jorge Gonçalves*

***Abstract*–This paper addresses the problem of robustly reconstructing network structure from input-output data. Previous work identified necessary and sufficient conditions for network reconstruction of LTI systems, assuming perfect measurements (no noise) and perfect system identification. This paper assumes that the previously identified necessary and sufficient conditions for network reconstruction are satisfied but here we additionally take into account noise and unmodelled dynamics (including nonlinearities). In order to identify the network structure that generated the data, we compute the smallest distances between the measured data and the data that would have been generated by particular Boolean networks. By striking a compromise between such distance and network complexity, we provide methods for revealing the correct network structure from data despite the presence of noise and nonlinearities.**

16.30 – 17.00

MAPK Module: Biological Basis, Structure, Mathematical Model and Dynamical Analyse
*Nataša A. Kablar*

***Abstract*–In this paper we present mitogen-activated protein kinase (MAPK) module: its biological definition, structure, and model. In modelling stage, we build on result of [9], and we include newly experimentally observed processes to capture more on real dynamic of cell: cross-linking among the different modules of MAPK and/or cross-linking with other pathways; influence of Phosphatase's, and influence of phosphorylated kinase kinase (KKP) found to have profound effect on module dynamics. For the chosen set of experimentally verifiable parameters we perform dynamic analyze. In investigation of bifurcation, we find Hopf Bifurcation as the only type of bifurcation observed.**

17.00 – 17.30

Estimation of Efficacy of HIV Nucleoside-Analogue Reverse Transcriptase Inhibitor (AZT) via Stochastic Modeling
*Samira Khalili, James M. Monaco, Antonios Armaou*

***Abstract*–In this work, the mechanisms by which nucleosideanalogue reverse transcriptase inhibitors (NRTIs), the most common class of drugs used in the treatment of HIV-1, exert their antiviral effects are analyzed and methods in which those known mechanisms could be employed to generate mathematical models for drug efficacy in terms of measurable physical values are identified. Drug concentration is considered as a time variant parameter which depends on the drug administration time and dosage.**

## Stochastic Control
*(Regular Session)*

**Room 13**

***Chair:*** *Alexander Yu. Mazurov*

15.30 – 16.00

Risk-Sensitive Dissipativity and Relevant Control Problems
*Alexander Yu. Mazurov, Pavel V. Pakshin*

***Abstract*–The paper is focused on control-affine stochastic Itô systems with control-quadratic storage functions. The concept of dissipativity with risk-sensitive storage function (RSSF) is proposed, with dissipativity criterion derived involving generalized Hamilton-Jacobi-Bellman inequalities. The proof utilizes a certain version of stochastic Artstein's inequality. Connections to risk-sensitive suboptimal control, the theory of games, invariant probabilistic measure and deterministic $H_\infty$-control are established. In linear-quadratic case the results are expressed via linear matrix inequalities (LMI). An example is provided.**

16.00 – 16.30

Hardy-Schatten Norms of Systems, Output Energy Cumulants and Linear Quadro-Quartic Gaussian Control
*Igor G. Vladimirov, Ian R. Petersen*

***Abstract*–This paper is concerned with linear stochastic control systems in state space. The integral of the squared norm of the system output over a bounded time interval is interpreted as energy. The cumulants of the output energy in the infinite-horizon limit are related to Schatten norms of the system in the Hardy space of transfer functions and the risksensitive performance index. We employ a novel performance criterion which seeks to minimize a combination of the average value and the variance of the output energy of the system per unit time. The resulting linear quadro-quartic Gaussian control problem involves the $H_2$ and $H_4$-norms of the closedloop system. We obtain equations for the optimal controller and outline a homotopy method which reduces the solution of the problem to the numerical integration of a differential equation initialized by the standard linear quadratic Gaussian controller.**

16.30 – 17.00

Anisotropy-Based Bounded Real Lemma
*Alexander P. Kurdyukov, Eugene A. Maximov, Michael M. Tchaikovsky*

***Abstract*–This paper extends the Bounded Real Lemma of the $H_\infty$-control theory to stochastic systems under random disturbances with imprecisely known probability distributions. The statistical uncertainty is measured in entropy theoretic terms using the mean anisotropy functional. The disturbance attenuation capabilities of the system are quantified by the anisotropic norm which is a stochastic counterpart of the $H_\infty$- norm. We develop a state-space criterion for the anisotropic norm of a linear discrete time invariant system to be bounded by a given threshold value. The resulting Anisotropy-based Bounded Real Lemma involves an inequality on the determinant of a matrix associated with a parameter-dependent algebraic Riccati equation.**

## Economics and Systems Theory
*(Regular Session)*

**Room 14**

***Chair:*** *Giacomo Como*

15.30 – 16.00

On Robustness Analysis of Large-Scale Transportation Networks
*Giacomo Como, Ketan Savla, Daron Acemoglu, Munther A. Dahleh, Emilio Frazzoli*

***Abstract*–In this paper, we study robustness properties of transportation networks with respect to its pre-disturbance equilibrium operating condition and the agents' response to the disturbance. We perform the analysis within a dynamical system framework over a directed acyclic graph between a single origin-destination pair. The dynamical system is composed of ordinary differential equations (ODEs), one for every edge of the graph. Every ODE is a mass balance equation for the corresponding edge, where the inflow term is a function of the agents' route choice behavior and the arrival rate at the base node of that edge, and the outflow term is function of the congestion properties of the edge.We consider disturbances that reduce the maximum flow carrying capacity of the links and define the margin of stability of the network as the minimum capacity that needs to be removed from the network so that the delay on all the edges remain bounded over time. For a given equilibrium operating condition, we derive upper bounds on the margin of stability under local information constraint on the agents' behavior, and characterize the route choice functions that yield this bound. We also setup a simple convex optimization problem to find the most robust operating condition for the network and determine edge-wise tolls that yield such an equilibrium operating condition.**

16.00 – 16.30

Combining the Frisch Scheme and Yule-Walker Equations for Identifying Multivariable Errors-in-Variables Models
*Roberto Diversi, Roberto Guidorzi*

***Abstract*–Errors–in–Variables (EIV) models, i.e. models whose stochastic environment considers measurement errors on both inputs and outputs are intrinsically more realistic than representations assuming an exact knowledge of**

**the input but are also more difficult to estimate. The difficulties increase in a non trivial way passing from the SISO and MISO cases to the MIMO one. This paper proposes a procedure for EIV identification of MIMO processes based on the Frisch scheme that assumes additional white noises on all inputs and outputs and shows its effectiveness by means of Monte Carlo simulations.**

16.30 – 17.00

Recursive Estimation of GARCH Processes
*László Gerencsér, Zsanett Orlovits, Balázs Torma*

***Abstract*–ARCH processes and their extensions known as GARCH processes are widely accepted for modelling financial time series, in particular stochastic volatility processes. The offline estimation of ARCH and GARCH processes have been analyzed under a variety of conditions in the literature. The main contribution of this paper is a rigorous convergence analysis of a recursive estimation method for GARCH processes with large stability margin under reasonable technical conditions. The main tool in the convergence analysis is an appropriate modification of the theory developed by Benveniste, Métivier and Priouret.**

17.00 – 17.30

Stochastic Calculus of Heston's Stochastic-Volatility Model
*Floyd B. Hanson*

***Abstract*–The Heston (1993) stochastic–volatility model is a square–root diffusion model for the stochastic–variance. It gives rise to a singular diffusion for the distribution according to Feller (1951). Due to the singular nature, the time-step must be much smaller than the lower bound of the variance. Several transformations are introduced that lead to proper diffusions including a transformation to an additive noise model with perfect-square solution, an exact, nonsingular solution special case and an alternate model. Simulation solution examples are also given.**

## Differential Geometric Methods for Computational Engineering Applications – 2 *(Invited Session)*

**Room 15**

***Organizers:*** *Knut Hüper, Christian Lageman*
***Chair:*** *Christian Lageman*

15.30 – 16.00

A Filtering Technique on the Grassmann Manifold
*Quentin Rentmeesters, Pierre-Antoine Absil, Paul van Dooren*

***Abstract*–In this paper, a filtering technique that deals with subspaces, i.e., points on the Grassmann manifold, is proposed. This technique is based on an observer design where the data points are seen as the outputs of a constant velocity dynamical model. An explicit algorithm is given to efficiently compute this observer on the Grassmann manifold. This approach is compared to a particle filtering technique and similar results are obtained for a lower computational cost. Some extensions of the filter are also proposed.**

16.00 – 16.30

Rotation Averaging and Weak Convexity
*Richard Hartley, Jochen Trumpf, Yuchao Dai*

***Abstract*–We generalize the concept of geodesic convexity in the Special Orthogonal Group SO(3) and apply the generalization to the discussion of rotation averaging. As a result we are able to derive strong and new theorems about the location of global minima of the rotation averaging cost function. A brief discussion of the relationship of our results to previous results from the literature will be provided, as well as an application to camera rig calibration in computer vision.**

16.30 – 17.00

On the Computation of Means on Grassmann Manifolds
*Knut Hüper, Uwe Helmke, Sven Herzberg*

***Abstract*–Given a set of data points on a Grassmann manifold sufficiently close to each other, one way to define their centroid or geometric mean is via the minimizer of a certain cost function. If one chooses the cost as the sum of squared geodesic distances between a given point and all the data points we end up with the definition of the Karcher mean. In this paper we analyze the critical points for this cost function.**

17.00 – 17.30

Joint Subspace Intersections as a Fitting Problem
*Christian Lageman, Knut Hüper*

***Abstract*–In this paper we consider the task of estimating a joint intersection of several subspaces from perturbed measurements of the subspaces. We treat this problem as a fitting problem on a Grassmann manifold. A potential application in face recognition is discussed.**