Preliminary Programme

ILAS 2011
in Braunschweig
August 22-26, 2011

June 1, 2011

Contents

Chapter 1

General Information

Sponsors

ILAS and the organizing committee gratefully acknowledge support of

NICONET

GAMM

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Registration

Registration will be possible on Sunday afternoon, there will also be a reception on Sunday evening.

Monday, August 22

08:50 - 09:00	**Opening Remarks**
09:00 - 10:00	**Plenary Lecture I** **Rajesh Pereira (University of Guelph)** Matrix Methods in Analytic Theory of Polynomials (for details on page 18)
10:00 - 10:30	*Coffee Break*
10:30 - 12:30	**Minisymposia I** (for details see pages 26-60)
12:30 - 14:00	*Lunch Break*
14:00 - 15:00	**Plenary Lecture II: NICONET speaker** **Zlatko Drmač (University of Zagreb)** Accurate and stable numerical linear algebra in control (for details on page 19)
15:00 - 15:30	*Coffee Break*
15:30 - 16:50	**Contributed Sessions I** (for details see pages 95-186)
16:50 - 17:00	*Short Break*
17:00 - 18:40	**Contributed Sessions II** (for details see pages 95-186)

Tuesday, August 23

09:00 - 10:00	**Plenary Lecture III: GAMM speaker** **Melina Freitag (University of Bath)** Tikhonov Regularization for Large Scale Inverse Problems (for details on page 20)
10:00 - 10:30	*Coffee Break*
10:30 - 12:30	**Young Researchers' Minisymposia I** (for details see pages 61-94)
12:30 - 14:00	*Lunch Break*
14:00 - 15:00	**Plenary Lecture IV: SIAM speaker** **Michiel Hochstenbach (TU Eindhoven)** Recent progress in the solution of discrete ill-posed problems (for details on page 21)
15:00 - 15:30	*Coffee Break*
15:30 - 16:50	**Contributed Sessions III** (for details see pages 95-186)
16:50 - 17:00	*Short Break*
17:00 - 18:40	**Contributed Sessions IV** (for details see pages 95-186)

Wednesday, August 24

09:00 - 10:00	**Plenary Lecture V** **Joseph M. Landsberg (Texas A&M University)** Multilinear algebra and geometry (for details on page 22)
10:00 - 10:30	*Coffee Break*
10:30 - 12:30	**Young Researchers' Minisymposia II** (for details see pages 61-94)
12:30 - 14:00	*Lunch Break*
14:00 - open end	**Exkursion & Conference Dinner**

Thursday, August 25

09:00 - 10:00	**Plenary Lecture VI** **Roland Hildebrand (Université Grenoble 1)** Linear group representations in the service of conic optimization (for details on page 23)
10:00 - 10:30	*Coffee Break*
10:30 - 12:30	**Minisymposia II** (for details see pages 26-60)
12:30 - 14:00	*Lunch Break*
14:00 - 15:00	**ILAS Buisness Meeting**
15:00 - 15:30	*Coffee Break*
15:30 - 17:30	**Minisymposia III** (for details see pages 26-60)
16:50 - 17:00	*Short Break*
17:40 - 18:40	**Contributed Sessions V** (for details see pages 95-186)

Friday, August 26

09:00 - 10:00	**Plenary Lecture VII** **Diederich Hinrichsen (Universität Bremen)** Interconnected systems with uncertain couplings: stability radii and sharp inclusion theorems (for details on page 24)
10:00 - 10:30	*Coffee Break*
10:30 - 12:30	**Minisymposia IV** (for details see pages 26-60)
12:30 - 14:00	*Lunch Break*
14:00 - 15:00	**Plenary Lecture VIII** **Daniel Potts (Chemnitz University of Technology)** Parameter Estimation for Exponential Sums (for details on page 25)
15:00 - 15:30	*Coffee Break*
15:30 - 17:10	**Contributed Sessions VI** (for details see pages 95-186)
17:10	**Closing**

Schedule: ILAS 2011 (Part I)

	Monday, 22.08.2011	Tuesday, 23.08.2011	Wednesday, 24.08.2011	Thursday, 25.08.2011	Friday, 26.08.2011
08:50 – 09:00	Opening Remarks				
09:00 – 10:00	**Plenary Lectures I** Rajesh Pereira	**Plenary Lectures III** Melina Freitag (GAMM speaker)	**Plenary Lectures V** Joseph Landsberg	**Plenary Lectures VI** Roland Hildebrand	**Plenary Lectures VII** Diederich Hinrichsen
10:00 – 10:30	Coffee Break	Coffee Break	Coffee Break	Coffee Break	Coffee Break
10:30 – 12:30	**Minisymposia I** MS3.1 Total positivity: recent Advances in Theory and Applications, Part I MS1.1 Tensor Decompositions, Part I MS5.1 Quasi- and Semi-separable matrices, Part I	**Young Researchers' Minisymposia I** YR4 Numerical Methods for the Solution of Algebraic Riccati Equations YR3 Combinatorial Matrix Theory YR7.1 Max-Plus, Part I YR2 The Theory of Orbits in Numerical Linear Algebra and Control Theory	**Young Researchers' Minisymposia II** YR1 Modern Methods for PDE Eigen-value Problems YR5 Matrix Means: Theory and Computation YR7.2 Max-Plus, Part II YR6 Parallel Computing in Numerical Linear Algebra	**Minisymposia II** MS6.1 Compressed Sensing and Sparse Approxi-mation Algorithms, Part I MS4.1 Matrix Polynomials and Their Eigen-problems, Part I MS5.2 Quasi- and Semi-separable matrices, Part II MS3.2 Total positivity: recent Advances in Theory and Applications, Part II	**Minisymposia IV** MS6.2 Compressed Sensing and Sparse Approxi-mation Algorithms, Part II MS4.2 Matrix Polynomials and Their Eigen-problems, Part II MS1.2 Tensor Decompositions, Part II
12:30 – 14:00	Lunch Break	Lunch Break	Lunch Break	Lunch Break	Lunch Break
14:00 – 15:00	**Plenary Lectures II** Zlatko Drmac (NICONET speaker)	**Plenary Lectures IV** Michiel Hochstenbach (SIAM speaker)	EXCURSION	**ILAS Business Meeting**	**Plenary Lectures VIII** Daniel Potts
15:00 – 15:30	Coffee Break	Coffee Break		Coffee Break	Coffee Break

Schedule: ILAS 2011 (Part II)

	Monday, 22.08.2011	Tuesday, 23.08.2011	Wednesday, 24.08.2011	Thursday, 25.08.2011	Friday, 26.08.2011
15:30 – 16:50	**Contributed Sessions I** CS1.1 Num. Methods for Linear Systems, Part I CS4.1 Matrix Functions and Equations, Part I CS13.1 Control, Part I CS7.1 Structured Matrices, Part I CS9 Stochastics	**Contributed Sessions III** CS1.3 Num. Methods for Linear Systems, Part III CS6.1 Generalized Inverses, Part I CS10.2 Graph Theory, Part II CS7.2 Structured Matrices, Part II CS12 Nonnegative Matrices	EXCURSION	**Minisymposia III** [Time: 15:30 – 17:30] MS2 Fiedler	**Contributed Sessions VI** CS8 Matrix Polynomials and Products CS11 Spectral Analysis and Sensitivity CS3 Singular Values and Least Squares CS17.4 Algebraic Structures and Matrix Theory, Part IV
16:50 – 17:00	Short Break	Short Break		Short Break	**Closing at approx. 17:10**
17:00 – 18:40	**Contributed Sessions II** CS1.2 Num. Methods for Linear Systems, Part II CS4.2 Matrix Functions and Equations, Part II CS14 Inequalities and Upper Bounds CS17.1 Algebraic Structures and Matrix Theory, Part I CS10.1 Graph Theory, Part I	**Contributed Sessions IV** CS2.1 Num. Methods for Eigenvalue Problems, Part I CS15 Differential and Difference Equations CS16 Information Theory CS17.2 Algebraic Structures and Matrix Theory, Part II CS13.2 Control, Part II		**Contributed Sessions V** [Time: 17:40 – 18:40] CS2.2 Num. Methods for Eigenvalue Problems, Part II CS6.2 Generalized Inverses, Part II CS5 Model and Dimension Reduction CS17.3 Algebraic Structures and Matrix Theory, Part III CS13.3 Control, Part III	
			Conference Dinner		

Chapter 2

Plenary Lectures

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09:00 - 10:00	**Rajesh Pereira**	
	Matrix Methods in Analytic Theory of Polynomials	p. 18
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	Accurate and stable numerical linear algebra in control	p. 19
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09:00 - 10:00	**Melina Freitag**	
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14:00 - 15:00	**Michiel Hochstenbach**	
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Wednesday, 24.08.2011	Chair: wed	**Room:**
09:00 - 10:00	**Joseph M. Landsberg**	
	Multilinear algebra and geometry	p. 22

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	Plenary Lectures VI	
Thursday, 25.08.2011	Chair: thu	**Room:**
09:00 - 10:00	**Roland Hildebrand**	
	Linear group representations in the service of conic optimization	p. 23
	Plenary Lectures VII & VIII	
Friday, 26.08.2011	Chair: fri	**Room:**
09:00 - 10:00	**Diederich Hinrichsen**	
	Interconnected systems with uncertain couplings: stability radii and sharp inclusion theorems	p. 24
14:00 - 15:00	**Daniel Potts**	
	Parameter Estimation for Exponential Sums	p. 25

- end of lectures -

Rajesh Pereira
University of Guelph

Matrix Methods in Analytic Theory of Polynomials

Monday, 22.08.2011, 09:00 - 10:00, Room to be filled in later by organizers

Polynomials are omnipresent in mathematics. Results on the location of the zeros of polynomials have proved useful in many parts of mathematics and science. Matrix theory has been very useful in studying polynomials. We will explore one facet of this application of matrix theory. In the 1940's, De Bruijn and Springer published a series of papers which proved some inequalities between the zeros of a polynomial and those of its derivative and conjectured that certain other inequalities of a similar type also hold. In 1960, Kurt Mahler introduced what later became known as the Mahler measure: $M(p) = \exp(\frac{1}{2\pi}\int_0^{2\pi} \ln(|p(e^{i\theta})|)d\theta$, a quantity of considerable interest to number theorists. It was only until forty years later that mathematicians realized that the inequalities of De Bruijn and Springer as well as many Mahler measure inequalities can be best studied using the majorization order. This insight opened up new ways of using matrix theory (where the majorization order occurs naturally) to prove results on polynomials. Roughly speaking the majorization order is a partial order on n-tuples which compares how spread out the elements of the n-tuple are. We will describe the majorization order and its application to polynomial theory; as well as some of the matrix techniques used to obtain these majorization results. We will explore the possibility of finding a similar partial order to measure the dispersion of the zeros of a polynomial projected onto the Riemann sphere and describe the connections that this problem has with quantum entanglement via the Majorana representation. We will discuss a number of open problems in this area including old unsolved conjectures such as Lehmer's problem on Mahler measure and Robinson's conjecture as well some recent questions motivated by quantum theory.

Zlatko Drmač
Department of Mathematics, Faculty of Science, University of Zagreb, Croatia

Accurate and stable numerical linear algebra in control

Monday, 22.08.2011, 14:00 - 15:00, Room to be filled in later by organizers

Control theory provides interesting and challenging problems to matrix theory and numerical linear algebra. Modern theoretical developments and exciting engineering applications demand efficient and numerically sound algorithms implemented as robust and accurate numerical software. Our aim is to illustrate how some recent developments in accurate linear algebra (accurate algorithms for eigenvalues and singular values, and corresponding theory) improve numerical computations in control theory, and contribute to software improvements. We will use few separate topics as case studies.
Advanced applications are based on high level packages, such as Matlab, and computing engines such as numerical software libraries LAPACK, SLICOT. We stress the importance of reliable numerical software and call for more mathematical rigor in the implementation phase (coding) and testing. To illustrate a problem, we show how adding just one " `WRITE(*,*) variable`" statement to a mission critical code based on the above mentioned libraries, or changing compiler options, completely changes the computed key parameters of a given linear time invariant (LTI) system. Such situations may occur only at certain distance to singularity, and some computational tasks (such as e.g. revealing a numerical rank) are usually performed and are crucial (and interesting) on data close to singularity. And, since many phenomena are possible when close to singularity, any ill–behavior of the software is usually attributed to ill–conditioning, bailed out by backward stability, and the true problem may remain inconspicuous. (We give an example of rank revealing QR factorization software (LINPACK, LAPACK, SLICOT,...) instability that had been circulating undetected in all relevant matrix computation libraries for more than thirty years.) This is certainly undesired behavior, even if such computation remains backward stable, and even if the computation is doomed to fail, due to ill–conditioning. We show the advantages of using state of the art matrix perturbation theory in rigorous numerical linear algebra software development.
Further, we show that carefully designed algorithms (based on detailed error analysis and perturbation theory) can e.g. simultaneously diagonalize a pair of positive definite matrices (e.g. for balancing the grammians of a LTI system) with small backward relative perturbations of matrix entries. This is much stronger stability than computing with backward error that is small in the matrix norm sense. As a result, stronger perturbation theory will identify better condition numbers and guarantee high accuracy.
We use other examples (computing certain canonical forms in control, model order reduction algorithms) to show how some instabilities undetected spoil the accuracy, and that they are removable by modifications inspired by error analysis and perturbation theory.

Melina Freitag
Dept. of Mathematical Sciences,University of Bath, Claverton Down, Bath BA2 7AY, UK

Tikhonov Regularization for Large Scale Inverse Problems

Tuesday, 23.08.2011, 09:00 - 10:00, Room to be filled in later by organizers

Variational data assimilation is a method for finding an estimate of the state of a system using both noisy observations and a nonlinear, imperfect model that predicts the state of the system. The particular method used in modern numerical weather prediction is four-dimensional variational data assimilation (otherwise known as 4DVar). The very large, ill-posed 4DVar minimisation problem can be written as a nonlinear Tikhonov regularization. We use this equivalence to examine well-known parameter choice methods for Tikhonov regularisation and apply them to variational data assimilation.

Michiel Hochstenbach
Department of Mathematics and Computer Science, TU Eindhoven, PO Box 513, 5600 MB Eindhoven, The Netherlands

Recent progress in the solution of discrete ill-posed problems

Tuesday, 23.08.2011, 14:00 - 15:00, Room to be filled in later by organizers

We will discuss several recently proposed methods for solving linear systems of equations or linear least-squares problems with a severely ill-conditioned matrix:

- a fractional Tikhonov approach, to avoid oversmoothing;
- a subspace restricted SVD approach, to include sensible apriori information;
- a simple method for Tikhonov regularization with a general regularization operator;
- a technique to combine several possible solutions;
- and a method to estimate the noise level in the right-hand side.

This contribution is joint work with Lothar Reichel (Kent State).

Joseph M. Landsberg
Texas A&M University

Multilinear algebra and geometry

Wednesday, 24.08.2011, 09:00 - 10:00, Room to be filled in later by organizers

I will begin by reviewing basic results from linear algebra and discuss the corresponding issues in multilinear algebra - many of them translate to open questions! Even a notion as simple as the rank of a matrix becomes a subtle concept when discussing “higher dimensional” matrices, i.e., tensors.

Some of these open questions are central to issues in areas such as computer science (complexity theory), engineering (signal processing) and physics (quantum information theory). The second part of my talk will discuss questions arising in these application areas.

Recently many researchers in geometry have become interested in these open questions and I will conclude with a survey of recent progress.

Roland Hildebrand
LJK, Université Grenoble 1 / CNRS, 51 rue des Mathématiques, BP53, 38041 Grenoble cedex, France

Linear group representations in the service of conic optimization

Thursday, 25.08.2011, 09:00 - 10:00, Room to be filled in later by organizers

In the first part of the talk, we will give a motivating introduction into conic optimization. Conic optimization is concerned with the optimization of a linear cost function $\langle c, x\rangle$ over the intersection of an affine subspace $L_A \subset \mathbf{R}^n$ with a convex cone $K \subset \mathbf{R}^n$. Many optimization problems from different areas can be converted into conic programs. The complexity of a conic program is primarily determined by the nature of the cone K. For conic programs over a particular subclass of cones, the *symmetric cones*, there exists a well-developed theory and a number of freely and commercially available solvers. Members of this subclass are the positive orthant $\mathbf{R}^n_+$, the Lorentz cone L_n, or the cones $S_+(m), H_+(m)$ of real symmetric or complex hermitian positive semi-definite $m \times m$ matrices. A conic program over these cones is called *linear, conic quadratic,* or *semi-definite program*. An extension of conic programming is *robust conic programming*, where the data of the conic program is only known to reside in some uncertainty region. If a cone K is representable as a linear projection of the intersection of one of the cones $S_+(m), H_+(m)$ with a linear subspace, then a conic program over K can be written as a semi-definite program and is hence easily solvable. Such a representation of K is called a *semi-definite representation*. For cones K relevant for conic programming, it is hence of importance to construct semi-definite representations. In the main part of the talk, we focus on the semi-definite representation of cones K which possess a nontrivial automorphism group $Aut(K)$. The linear representations of $Aut(K)$ can in several ways serve the construction of semi-definite representations of K.
Let $G \subset GL(V)$ be a linear representation of $Aut(K)$ on an m-dimensional real or complex vector space V. The mapping $A \mapsto gAg^*$, $g \in G$, then represents a linear action of $Aut(K)$ on the space of real symmetric or complex hermitian $m \times m$ matrices. In particular, this action leaves the cone $S_+(m)$ or $H_+(m)$ of positive semi-definite matrices invariant. We will present conditions under which this allows the construction of a semi-definite representation of K as a linear slice of the positive semi-definite cone, or, on the contrary, rules out possible approaches. A second application of the linear representations of $Aut(K)$ is in the reduction in size and complexity of existing semi-definite representations of K. The basic tool used here is Schur's lemma.
As an example, we briefly outline the recent construction of a semi-definite representation of the tensored cone $K = L_n \otimes L_{n'}$, which possesses an especially large automorphism group [Hildebrand R., An LMI description for the cone of Lorentz-positive maps, Linear Multilinear A. 55(6):551–573, 2007], [Hildebrand R., An LMI description for the cone of Lorentz-positive maps II, Linear Multilinear A., to appear, www.informaworld.com/10.1080/03081087.2010.486243]. Robust conic quadratic programs with ellipsoidal uncertainty region can be reduced to ordinary conic programs over K, providing an application of the presented theory.

Diederich Hinrichsen
Universität Bremen, Germany

Interconnected systems with uncertain couplings: stability radii and sharp inclusion theorems

Friday, 26.08.2011, 09:00 - 10:00, Room to be filled in later by organizers

This paper deals with a subject area where linear control theory meets linear algebra. We consider composite systems consisting of time-invariant linear subsystems with an arbitrarily prescribed interconnection structure. The subsystems interact via norm bounded couplings. Assuming that each subsystem is stable, the problem is to determine which bounds on the couplings guarantee that the interconnected system is stable. Extending Gershgorin's approach, the interconnected systems are viewed as perturbations of the block-diagonal system representing the collection of disconnected subsystems. We define the associated *spectral value sets* and *stability radii* and derive formulas for their computation. In the special case where all the subsystems are one-dimensional, our results imply the classical eigenvalue inclusion theorems of A. Brauer (1947) and R. A. Brualdi (1982). Moreover, they show that the inclusion results of Brauer and Brualdi are sharp for the corresponding perturbation structures.
In order to analyze the effect of *time-varying* couplings, we introduce scaled Riccati equations and obtain explicit formulas for the corresponding stability radii. From these formulas we derive necessary and sufficient conditions under which the stability radii with respect to time-invariant and time-varying couplings are equal.

This contribution is based on joint work with A. J. Pritchard (University of Warwick) (†) and M. Karow (Technical University Berlin).

Daniel Potts
Chemnitz University of Technology, Germany

Parameter Estimation for Exponential Sums

Friday, 26.08.2011, 14:00 - 15:00, Room to be filled in later by organizers

Many applications in electrical engineering, signal processing, and mathematical physics lead to the following problem: Recover the pairwise different frequencies $f_j \in (-\pi, \pi)$, the complex coefficients $c_j \neq 0$, and the number $M \in \mathbf{N}$ in the exponential sum

$$h(x) := \sum_{j=1}^{M} c_j \, \mathrm{e}^{\mathrm{i} f_j x} \quad (x \in \mathbf{R}),$$

if perturbed sampled data $\tilde{h}_k := h(k) + e_k$ $(k = 0, \ldots, 2N)$ are given, where e_k are small error terms. This nonlinear problem of finding the frequencies and coefficients can be split into two problems by original ideas of G. de Prony (1795). To obtain the frequencies, we solve a singular value problem of the rectangular Hankel matrix $\mathbf{H} = \big(h(k+l)\big)_{k,l=0}^{2N-L,L}$ and find the frequencies via roots of a convenient polynomial of degree L. To obtain the coefficients, we use the frequencies to solve a linear Vandermonde–type system. We apply matrix perturbation theory such that we can describe the numerical behaviour of the approximate Prony method in detail. The stability of the solution is discussed in the square and uniform norm too. Furthermore we present multivariate generalisations. Numerical experiments show the performance of our method.

This contribution is joint work with Manfred Tasche (University of Rostock, Germany).

Chapter 3

Minisymposia

MS1

Lars Grasedyck and Eugene Tyrtyshnikov
IGPM RWTH Aachen, and INM RAS Moscow

Tensor Decomposition and Approximation

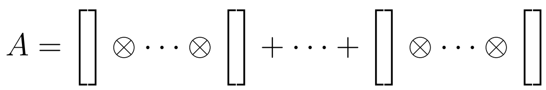
Monday, 22.08.2011, and Friday, 26.08.2011, 10:30 - 12:30

The (numerical) linear algebra related to tensor computations plays an immensely powerful role in theoretical and applied sciences: applied mathematics, biology, chemistry, information sciences, physics and many other areas. The main focus of this minisymposium is the treatment of high-order or high-dimensional tensors

$$A \in \mathbb{K}^{\mathcal{I}_1 \times \cdots \times \mathcal{I}_d}$$

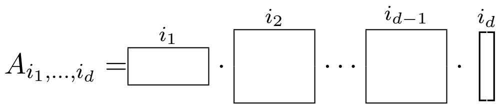
These require special techniques in order to allow a representation and approximation for high dimension d (cf. the curse of dimension). Typical examples are the canonical polyadic (CP) format

$$A_{i_1,\ldots,i_d} = \sum_{\nu=1}^{k} a_{i_1}^{(1,\nu)} \cdots a_{i_d}^{(d,\nu)}, \qquad a^{(j,\nu)} \in \mathbb{K}^{\mathcal{I}_\nu},$$



the tensor train (TT) representation

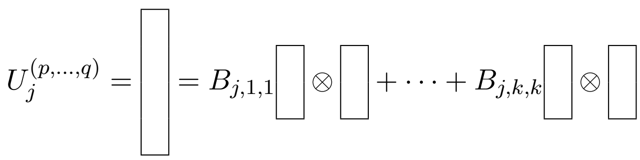
$$A_{i_1,\ldots,i_d} = G^{(1,i_1)} \cdots G^{(d,i_d)}, \qquad G^{(1,i)} \in \mathbb{K}^{1\times k}, G^{(\nu,i)} \in \mathbb{K}^{k\times k}, G^{(d,i)} \in \mathbb{K}^{k\times 1},$$



as well as the recursively defined hierarchical Tucker ($\mathcal{H}$-Tucker) format

$$A_{i_1,\ldots,i_d} = U_1^{(1,\ldots,d)},$$

$$U_j^{(p,\ldots,q)} = \sum_{\nu=1}^{k} \sum_{\mu=1}^{k} B_{j,\nu,\mu} U_\nu^{(p,\ldots,r)} \otimes U_\mu^{(r+1,\ldots,q)} \qquad \in \mathbb{K}^{\mathcal{I}_p \times \cdots \times \mathcal{I}_q}$$



All of these are based on notions of rank for entities beyond matrices, but still they rely on techniques from (numerical) linear algebra. The talks of this minisymposium will introduce into the topic and deliver state-of-the-art results in the numerical treatment of PDEs with stochastic and/or many parameters, quantum chemistry, black-box tensor reconstruction and many more.

Speakers

	MS1.1: Tensor Decomposition and Approximation (PART I)	
Monday, 22.08.2011		**Room:**
10:30 - 11:00	**Christine Tobler**	
	A MATLAB *toolbox for tensors in hierarchical Tucker format*	p. 29
11:00 - 11:30	**Jonas Ballani**	
	Black Box Approximation of High-Dimensional Functions in Hierarchical Tucker Format	p. 29
11:30 - 12:00	**Melanie Kluge**	
	Tensor Completion in Hierarchical Tucker Format	p. 30
12:00 - 12:30	**Sebastian Holtz**	
	Direct optimization algorithm and convergence	p. 30
	MS1.2: Tensor Decomposition and Approximation (PART II)	
Friday, 26.08.2011		**Room:**
10:30 - 11:00	**Ivan Oseledets**	
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11:00 - 11:30	**Sergey Dolgov**	
	A gray-box DMRG algorithm for tensor structured solution to linear systems	p. 31
11:30 - 12:00	**Laurent Sorber**	
	A visual perspective on tensor approximation	p. 32
12:00 - 12:30	**Ignat Domanov**	
	On the Canonical Polyadic Decomposition of symmetric tensors with block Hankel factor matrices	p. 32

- end of session -

Christine Tobler
ETH Zurich, Switzerland

A MATLAB toolbox for tensors in hierarchical Tucker format

Monday, 22.08.2011, 10:30 - 11:00, Room to be filled in later by organizers

The hierarchical Tucker format allows the efficient storage and manipulation of certain tensors of possibly high order. The `htucker` toolbox is introduced, which provides a convenient way to work with this format in MATLAB. It offers the approximation of a given tensor in hierarchical Tucker format, basic operations within the format as well as a set of tools for the development of higher-level algorithms.
As an application, algorithms for solving high-dimensional eigenvalue problems, e.g. the Schrödinger equation, are shown.

This contribution is joint work with Daniel Kressner (ETH Zurich, Switzerland).

Jonas Ballani
Max Planck Institute for Mathematics in the Sciences

Black Box Approximation of High-Dimensional Functions in Hierarchical Tucker Format

Monday, 22.08.2011, 11:00 - 11:30, Room to be filled in later by organizers

We consider the problem of approximating a multivariate function f depending on d parameters. Such functions frequently arise in the field of optimisation and stochastics with applications in e.g. finance and physics. For smooth functions, a standard interpolation scheme leads to the task of approximating a d-dimensional tensor $A \in \mathrm{R}^{n_1 \times \dots \times n_d}$ which is given by the values of f at the interpolation points. If A can be approximated in a low-rank tensor format, an approximation of f can be evaluated very efficiently for any given parameter tuple even if the dimension d gets large (say $d > 10$). We propose a (heuristic) approach that finds an approximation of A in the so-called hierarchical Tucker format in a black box fashion. The number of tensor entries that need to be evaluated lies in $\mathcal{O}(dk^3 + \log(d)k^2 \sum_{i=1}^{d} n_i)$, where k is a small integer. The construction parallelises with respect to the order d and is adaptive in the sense that the rank parameter k is found automatically for a given target accuracy ε. We present numerical examples that illustrate the potential of the proposed method.

This contribution is joint work with Lars Grasedyck and Melanie Kluge (RWTH Aachen, Germany).

Melanie Kluge
RWTH Aachen, IGPM

Tensor Completion in Hierarchical Tucker Format

Monday, 22.08.2011, 11:30 - 12:00, Room to be filled in later by organizers

For the approximation of order d tensors $A \in \mathbb{R}^{n\times\cdots\times n}$ the hierarchical ($\mathcal{H}$-) Tucker format is useful [W.Hackbusch and S.Kühn, A new scheme for the tensor representation, J. Fourier Anal. Appl. 2009 (15)], [Lars Grasedyck, Hierarchical Singular Value Decomposition of Tensors, SIAM J. Matrix Anal. Appl. 2010 (31)]. It is a dimension-multilevel variant of the Tucker format and strongly related to the TT format.
In the $\mathcal{H}\text{-Tucker}$ format, the sparsity of the representation of a tensor is determined by the hierarchical rank which is the rank of certain matricizations of the tensor. The approximation of a tensor in this format is based on two concepts: One has to approximate the matricizations by low rank, and one has to ensure that the approximations are nested [J. Ballani, L. Grasedyck and M. Kluge, Black Box Approximation of Tensors in Hierarchical Tucker Format, www.dfg-spp1324.de, preprint 2010], [I.V. Oseledets and E.E. Tyrtyshnikov, TT-cross approximation for multidimensional arrays, Linear Algebra and its Applications 2010 (432)]. We approach the matrices by an ALS like algorithm that uses the structure of the $\mathcal{H}\text{-Tucker}$ format.

This contribution is joint work with Jonas Ballani (MPI MIS Leipzig, Germany) and Lars Grasedyck (RWTH Aachen, Germany).

Sebastian Holtz
Technische Universität Berlin, Germany

Direct optimization algorithm and convergence

Monday, 22.08.2011, 12:00 - 12:30, Room to be filled in later by organizers

Recent achievements in the field of tensor product approximation provide promising new formats for the representation of tensors in form of tree tensor networks. In contrast to the canonical r-term representation , these new formats provide stable representations, while the amount of required data is only slightly larger. The TT format, a simple special case of the hierarchical Tucker format, is a prototype for such a practical low rank tensor representation, corresponding to the method of matrix product states (MPS) known from quantum information theory.
The present talk is concerned with iterative optimization methods used for the solution of linear equations and eigenvalue problems in the framework of TT tensors. We consider the convergence of an iteration method based on a linear parametrization of the tangent space. We relate this approach with Jacobi like and with Gauss-Seidel like iteration methods for TT tensors. The Gauss-Seidel like methods are ALS (alternating linear schemes) and modifications like DMRG.

This contribution is joint work with Thorsten Rohwedder (TU Berlin, Germany) and Reinhold Schneider (TU Berlin, Germany).

Ivan Oseldets
t.b.a.

t.b.a.

Friday, 26.08.2011, 10:30 - 11:00, Room to be filled in later by organizers

t.b.a.

Sergey Dolgov
Institute of Numerical Mathematics Russian Academy of Sciences

A gray-box DMRG algorithm for tensor structured solution to linear systems

Friday, 26.08.2011, 11:00 - 11:30, Room to be filled in later by organizers

Tensor approximations and structured data representations appear to be an efficient approach to high-dimensional problems. A lot of techniques for a variety of problems were developed using so-called Canonical tensor format, Tucker format and afterward the Tensor Train and H-Tucker formats. The similar to the TT structure, the Matrix Product States is actively used in the quantum physics community to represent quantum states of many-body systems [J.I. Cirac et al., Matrix Product State Representations]. To solve eigenvalue problems in this format, the so-called Density Matrix Renormalization Group algorithm [S. R. White, Density-matrix algorithms for quantum renormalization groups] was developed to minimize the Rayleigh quotient. The same approach might be used for quite a general optimization problem. In this work, solution of linear systems as an optimization of functionals $(Ax, x) - 2(f, x)$ and $||Ax - f||^2$ is considered. A general scheme was presented in [S. Holtz et al, The Alternating Linear Scheme for Tensor Optimisation in the TT Format], but to construct an efficient method, several additional techniques are required. An efficient preconditioner for reduced linear problems, advanced decimation strategy and a way to control the residual will be presented.

This contribution is joint work with Ivan Oseledets (INM RAS, Moscow).

Laurent Sorber
Department of Computer Science, Katholieke Universiteit Leuven, Belgium

A visual perspective on tensor approximation

Friday, 26.08.2011, 11:30 - 12:00, Room to be filled in later by organizers

Multi-way arrays are tensor representations that suffer from the curse of dimensionality. That is, the number of elements in an N-way array grows exponentially with the number of dimensions N, also known as the order of the associated tensor. In order to keep the computational and storage cost of working with tensors manageable, several tensor approximation methods have been proposed. Among these are the canonical polyadic decomposition (CPD), multilinear SVD (MLSVD), hierarchical SVD (also known as $\mathcal{H}$-Tucker), tensor trains (TT) and block term decompositions (BTD). We present a new visual perspective on these decompositions and illustrate their use in video coding.

This work was done in cooperation with Nick Vannieuwenhoven (K.U.Leuven, Belgium), Dirk Nuyens (K.U.Leuven, Belgium), Lieven De Lathauwer (K.U.Leuven Kortrijk, Belgium) and Marc Van Barel (K.U.Leuven, Belgium).

Ignat Domanov
Group Science, Engineering and Technology, KULeuven Campus Kortrijk and
Department of Electrical Engineering (ESAT), SCD, Katholieke Universiteit Leuven

On the Canonical Polyadic Decomposition of symmetric tensors with block Hankel factor matrices

Friday, 26.08.2011, 12:00 - 12:30, Room to be filled in later by organizers

Our goal is to compute the Canonical Polyadic Decomposition (CPD) of a third order cubical tensor $\mathcal{T}$ of which all factor matrices are (up to conjugation) equal to the same block Hankel matrix.
Such a problem appears in the context of the blind identification of convolutive mixtures: tensor $\mathcal{T}$ is estimated from the data, and the columns of the factor matrix contain the mixing coefficients.
There exist no explicit algebraic solutions for this particular problem. Alternating algorithms appear not to work well, especially in the case of noisy data. We focus on optimization algorithms. First, we prove that the cost function f always has a minimum. (That is not the case for arbitrary tensors). Second, we present an explicit expression of the complex gradient of f and show that the critical points of f are fixed points of a particular mapping. Then we design a cheap algorithm based on the Krasnoselskii iteration to find critical points of f.
This contribution is joint work with Lieven De Lathauwer (Group Science, Engineering and Technology, KULeuven Campus Kortrijk and Department of Electrical Engineering (ESAT), SCD, Katholieke Universiteit Leuven).

MS2

Richard Brualdi and Hans Schneider
University of Wisconsin, Madison

Minisymposium in honor of Miroslav Fiedler

Thursday, 25.08.2011, 15:30 - 17:30

The speakers in this minsymposium are Steve Mackey, Vladimir Nikiforov, Sergei Sergeev, and Jeff Stuart.
The talks will highlight four general areas of the many mathematical contributions of Fiedler and how they have influenced and continue to influence developments in these areas: Companion-like Matrices and their Application, Spectral Graph Theory, Diagonal Scaling, Special Matrices.

Speakers

	MS2: Minisymposium in honor of Miroslav Fiedler	
Thursday, 25.08.2011		**Room:**
15:30 - 16:00	**D. Steven Mackey**	
	M. Fiedler's work on companion-like matrices and its influence on later developments and applications	p. 35
16:00 - 16:30	**Vladimir Nikiforov**	
	The influence of Miroslav Fiedler's work on Spectral Graph Theory	p. 35
16:30 - 17:00	**Sergeĭ Sergeev**	
	Fiedler-Pták scaling in max algebra	p. 36
17:00 - 17:30	**Jeffrey Stuart**	
	Highlights of Miroslav Fiedler's Work With Special Matrices	p. 36

- end of session -

D. Steven Mackey
Western Michigan University

M. Fiedler's work on companion-like matrices and its influence on later developments and applications

Thursday, 25.08.2011, 15:30 - 16:00, Room to be filled in later by organizers

t.b.a

Vladimir Nikiforov
University of Memphis, USA

The influence of Miroslav Fiedler's work on Spectral Graph Theory

Thursday, 25.08.2011, 16:00 - 16:30, Room to be filled in later by organizers

Miroslav Fiedler is well-known for his numerous beautiful and lasting contributions to Linear Algebra and Combinatorics. In particular, during all of his mathematical career he has had a keen interest in Graph Theory. No wonder then that his work and ideas have shaped major directions in Spectral Graph Theory. He is best known for his ground-breaking study of the graph Laplacian, but in addition to that, much of his other work on matrices can be related to spectra of graphs: for instance, one of his theorems on elliptic matrices generalizes Smith's spectral characterization of complete multipartite graphs. This talk will attempt to outline the influence of Prof. Fiedler's work on Spectral Graph Theory and some of its yet unexplored potential.

Sergeĭ Sergeev
INRIA and CMAP École Polytechnique (France)

Fiedler-Pták scaling in max algebra

Thursday, 25.08.2011, 16:30 - 17:00, Room to be filled in later by organizers

We will describe the role of particular diagonal similarity scaling introduced by Fiedler and Pták (Czech Math. Journal, 1967). This scaling, also known as visualization, is essential for some problems in max algebra (periodicity of max-algebraic powers, properties of commuting matrices), and applications.

Jeffrey Stuart
Pacific Lutheran University, Tacoma, WA 98447 USA

Highlights of Miroslav Fiedler's Work With Special Matrices

Thursday, 25.08.2011, 17:00 - 17:30, Room to be filled in later by organizers

In their well-known 1962 paper, Miroslav Fiedler and Vlastimil Pták initiated the systematic study of Z-matrices, M-matrices, and their multifold relationships with other classes of matrices. In the fifty years since the publication of that paper, special classes of matrices with combinatorial structure has been an extremely fruitful field of research in which Professor Fiedler has continued to produce important work. In this talk, we will examine some those results with a focus on special classes of matrices with close connections to Z-matrices and M-matrices.

MS3

Plamen Koev and Juan Manuel Peña
San José State University and Universidad de Zaragoza

Total positivity: recent advances in theory and applications

Monday, 22.08.2011, and Thursday, 25.08.2011, 10:30 - 12:30

A matrix is called *totally positive* (*totally nonnegative*) if every minor is positive (non-negative). Such matrices arise in a remarkable variety of ways within mathematics and in many areas to which mathematics is applied. These include

- differential and integral equations,
- function theory,
- approximation theory,
- matrix analysis,
- combinatorics,
- numerical mathematics,
- statistics,
- computer aided geometric design,
- mathematical finance,
- mechanics

Total positivity is a multidisciplinary subject with one century of history. The research on total positivity has considerably increased during the last years. Our intent is to assemble a broadly based group of speakers with a common interest in total positivity to bring diverse perspectives and tools to bear on a few important and related problems in the subject. It is our hope that the participants of this minisymposium will become aware of some important results and problems in total positivity and that additionally old or new problems from other disciplines related to positivity can be identified which may also be related to total positivity.

Speakers

	MS3.1: Total positivity: recent advances in theory and applications (PART I)	
Monday, 22.08.2011		**Room:**
10:30 - 11:00	**Charles Johnson** *The Distribution of Rank in the Submatrices of a TN Matrix*	p. 39
11:00 - 11:30	**Rafael Cantó** *Characterizations of totally positive and totally negative rectangular matrices*	p. 39
11:30 - 12:00	**Alvaro Barreras** *Jacobi sign regular matrices*	p. 40
12:00 - 12:30	**Olga Kushel** *On conic sets, invariant for matrices with real spectrum*	p. 40

	MS3.2: Total positivity: recent advances in theory and applications (PART II)	
Thursday, 25.08.2011		**Room:**
10:30 - 11:00	**José-Javier Martínez** *Accurate bidiagonal factorization of certain classes of totally positive matrices*	p. 41
11:00 - 11:30	**Plamen Koev** *Computing Jordan Blocks of Irreducible Totally Nonnegative Matrices*	p. 41
11:30 - 12:00	**Juan Manuel Peña** *Computations with matrices with special bidiagonal factorizations*	p. 42

- end of session -

Charles Johnson
College of William and Mary

The Distribution of Rank in the Submatrices of a TN Matrix

Monday, 22.08.2011, 10:30 - 11:00, Room to be filled in later by organizers

The possible arrangements of rank in the submatrices of a totally nonnegative (TN) matrix is far from as arbitrary as in a general matrix. The severe limitations on the possible 0 entries ("shadows") are an example and the tip of an iceberg. These 0 limitations have long been known, but, as TN matrices are not preserved by the taking of compounds, general statements about rank do not follow. We give here a reasonably complete description of the possible ranks of submatrices of a TN matrix that is not totally positive.

This represents joint work with Shaun Fallat.

Rafael Cantó
Instituto de Matemática Multidisciplinar. Univ. Politécnica de Valencia. Spain.

Characterizations of totally positive and totally negative rectangular matrices

Monday, 22.08.2011, 11:00 - 11:30, Room to be filled in later by organizers

An $m \times n$ real matrix A is said to be totally positive (strictly totally positive) if all its minors are nonnegative (positive) and are abbreviated as TP and STP, respectively. If, instead, all minors of A are nonpositive (negative), A is called totally nonpositive (totally negative) and are abbreviated as t.n.p. and t.n., respectively.
These types of matrices have an important role in the various branches of mathematics and other sciences. The TP and STP square matrices have been studied by several authors who have obtained properties and characterizations in terms of the factorizations obtained by Gaussian or Neville elimination that allow one to reduce the number of minors to be checked in order to decide if a matrix is TP and STP. For square t.n. matrices and for nonsingular t.n.p. matrices, a characterization in terms of the parameters obtained from Neville elimination is also known using the factors of their LDU factorization. Now, we consider rectangular matrices and study characterizations of these types of matrices by minors, by their full rank factorization and by their thin QR factorization to significantly reduce the number of minors to be checked in order to decide the total positivity (negativity) of a rectangular matrix.

This contribution is joint work with Ana M. Urbano (IMM, UPV, Spain) and it was supported by the Spanish DGI grant MTM2010-18228 and the UPV PAID-06-10.

Alvaro Barreras
Universidad de Zaragoza, Spain

Jacobi sign regular matrices

Monday, 22.08.2011, 11:30 - 12:00, Room to be filled in later by organizers

An $n \times n$ matrix A is sign regular if, for each $k = 1, \ldots, n$, all minors of order k have the same sign or are zero. If all minors are nonnegative, then we say that A is totally positive. A matrix $A = (a_{ij})_{1 \leq i,j \leq n}$ is Jacobi (or tridiagonal) if $a_{ij} = 0$ whenever $|i - j| > 1$. Totally positive Jacobi matrices have already been characterized by a reduced number of minors. In this talk several characterizations of nonsingular sign regular Jacobi matrices are presented.

This contribution is a joint work with Juan Manuel Peña (Universidad de Zaragoza, Spain).

Olga Kushel
Technische Universität Berlin, Germany

On conic sets, invariant for matrices with real spectrum

Monday, 22.08.2011, 12:00 - 12:30, Room to be filled in later by organizers

A linear operator A in the finite-dimensional space R^n is called *generalized strictly sign-regular*, if there exist a sequence of proper cones $K_1 \subset R^n$, $K_2 \subset \wedge^2 R^n$, $\ldots$, $K_n \subset \wedge^n R^n$ and a sequence of numbers $\epsilon_1, \ \ldots, \ \epsilon_n$, each equal to ± 1, such that $\epsilon_1 A(K_1 \setminus \{0\}) \subseteq \mathrm{int}(K_1)$ and $\epsilon_j (\wedge^j A)(K_j \setminus \{0\}) \subseteq \mathrm{int}(K_j)$ for every j $(j = 2, \ \ldots, \ n)$. It is shown, that this is equivalent to the statement that all the eigenvalues of A are real and different in modulus from each other. The conic sets, invariant for generalized strictly sign-regular operators, are also studied.

José-Javier Martínez
Universidad de Alcalá, Spain

Accurate bidiagonal factorization of certain classes of totally positive matrices

Thursday, 25.08.2011, 10:30 - 11:00, Room to be filled in later by organizers

Among the existing literature on bidiagonal factorizations of totally positive matrices, the concept of $\mathcal{BD}(A)$ developed by P. Koev starting from previous work of other authors, along with many new results related to that factorization [P. Koev, *Accurate computations with totally nonnegative matrices*, SIAM J. Matrix Anal. Appl. 29 (2007), no. 3, 731-751], are remarkable because of their applicability. In this context, for the purpose of accurate computations with totally positive matrices it is crucial to compute an accurate bidiagonal decomposition.
In this talk we will review the subject of computing, with high relative accuracy, a bidiagonal decomposition $\mathcal{BD}(A)$ for certain classes of totally positive matrices such as Cauchy-Vandermonde matrices [J. J. Martínez and J. M. Peña, *Factorizations of Cauchy-Vandermonde matrices*, Linear Algebra Appl. 284 (1998) 229-237] or Bernstein-Vandermonde matrices [A. Marco and J. J. Martínez, *A fast and accurate algorithm for solving Bernstein-Vandermonde linear systems*, Linear Algebra Appl. 422 (2007) 616-628]. Some illustrative examples of the application of that accurate factorization will be shown.

This contribution is joint work with Ana Marco (Universidad de Alcalá, Spain).

Plamen Koev
San Jose State University

Computing Jordan Blocks of Irreducible Totally Nonnegative Matrices

Thursday, 25.08.2011, 11:00 - 11:30, Room to be filled in later by organizers

In 2005 Fallat and Gekhtman fully characterized the Jordan Canonical Form of the irreducible totally nonnegative matrices. In particular, all nonzero eigenvalues are simple and the possible Jordan structures of the zero eigenvalues are well understood and described. Starting with the bidiagonal decomposition of these matrices, we present an algorithm for computing all the eigenvalues, including the Jordan blocks, to high relative accuracy in what we believe is the first example of Jordan structure being computed accurately in the presence of roundoff errors.

Juan Manuel Peña
Universidad de Zaragoza, Spain

Computations with matrices with special bidiagonal factorizations

Thursday, 25.08.2011, 11:30 - 12:00, Room to be filled in later by organizers

Bidiagonal factorization has played a crucial role for nonsingular totally nonnegative matrices (matrices with all their minors nonnegative). Important theoretical properties of these matrices can be deduced from this factorization. Moreover, the bidiagonal factorization allows us to perform accurately many computations with these matrices. There are other classes of matrices admitting a bidiagonal factorization. For instance, the class of strictly sign regular matrices, where the factorization can differ from that of totally nonnegative matrices. Here we present some recent advances on the computation with matrices with special bidiagonal factorizations.

This contribution is joint work with Alvaro Barreras (Universidad de Zaragoza, Spain).

MS4

Françoise Tisseur and Ion Zaballa
The University of Manchester, UK and Universidad del País Vasco-Euskal Herriko Unibertsitatea, Spain

Matrix Polynomials and their Eigenproblems

Thursday, 25.08.2011, and Friday, 26.08.2011, 10:30 - 12:30

Polynomial eigenvalue problems arise in a wide variety of science and engineering applications, including classical structural mechanics, automatic control, molecular dynamics, gyroscopic systems,and optical waveguide design. These problems present many mathematical and computational challenges. The trend to towards extreme designs leads to eigenproblems with poor conditioning, while the physics of the system leads to algebraic structure that numerical methods should preserve if they are to provide physically meaningful results.

The purpose of this minisymposium is to present recent developments on matrix polynomials and their eigenproblems on the theoretical and computational sides as well as in applications. A range of topics will be covered, including linearization, perturbation theory, structure preservation, numerical methods and the use of polynomial matrices in control.

Speakers

MS4.1: Matrix Polynomials and their Eigenproblems (PART I)		
Thursday, 25.08.2011		**Room:**
10:30 - 11:00	**Volker Mehrmann** *Skew-symmetric matric polynomials and their application*	p. 45
11:00 - 11:30	**D. Steven Mackey** *The Elementary Divisor Structure of Quadratic Matrix Polynomials*	p. 45
11:30 - 12:00	**Sk Safique Ahmad** *Pseudospectra and backward error analysis for singular multiparameter eigenvalue problem*	p. 46
12:00 - 12:30	**Karl Meerbergen** *The solution of a nonlinear eigenvalue problem using polynomial eigenvalue solvers*	p. 46

MS4.2: Matrix Polynomials and their Eigenproblems (PART II)		
Friday, 26.08.2011		**Room:**
10:30 - 11:00	**Nicos Karkanias** *Polynomial Matrices, Approximate GCD and Control Theory*	p. 47
11:00 - 11:30	**Fernando De Terán** *Fiedler linearizations of matrix polynomials*	p. 47
11:30 - 12:00	**Stavros Vologiannidis** *Extended Fiedler linearizations and eigenvector recovery*	p. 48
12:00 - 12:30	**Ion Zaballa** *Eigenstructure of Real Symmetric Quadratic Matrix Polynomials*	p. 48

- end of session -

Volker Mehrmann
Technische Universität Berlin

Skew-symmetric matric polynomials and their applications

Thursday, 25.08.2011, 10:30 - 11:00, Room to be filled in later by organizers

We discuss the numerical solution of several classes of structured polynomial eigenvalue problems, by embedding the problem into an eigenvalue problem for a skewsymmetric matrix polynomial. For this we present a new staircase algorithm as well as a new trimmed linearization procedure. Recent results on Smith forms for skew-symmetric matrix polynomials show that they always have structure preserving linearizations and we discuss how these can be used to obtain a united eigensolver for most structured polynomial eigenvalue problems.

This contribution is joint work with Hongguo Xu, (Univ. of Kansas).

D. Steven Mackey
Western Michigan University

The Elementary Divisor Structure of Quadratic Matrix Polynomials

Thursday, 25.08.2011, 11:00 - 11:30, Room to be filled in later by organizers

For regular matrix pencils, any list of elementary divisors is possible, as is easily seen from the Weierstrass canonical form. Such is not the case, though, for quadratic matrix polynomials. The main goals of this talk are to characterize those elementary divisor lists that can ever occur as the elementary divisors of some regular quadratic polynomial, and to sketch some consequences of this characterization. In particular, we are able to completely describe those regular matrix polynomials $P(\lambda)$ that admit a strong quadratification $Q(\lambda)$, i.e., a quadratic polynomial Q with exactly the same elementary divisors as P. As time permits, the analogous issues for various classes of structured quadratic matrix polynomials, e.g., palindromic and Hermitian quadratic polynomials, will also be discussed.

This contribution is joint work with Fernando De Terán and Froilán Dopico (Universidad Carlos III de Madrid, Spain), and Maha Al-Ammari and Françoise Tisseur (The University of Manchester, UK).

Sk Safique Ahmad
IIT Indore

Pseudospectra and backward error analysis for singular multiparameter eigenvalue problems

Thursday, 25.08.2011, 11:30 - 12:00, Room to be filled in later by organizers

In this work we propose a general framework of structured backward error analysis of an approximate n-tuple of eigenvalues of a structured multiparameter eigenvalue problems with Hermitian, skew-Hermitian, even and odd. We construct a minimal structured perturbation such that an approximate n-tuple of eigenvalues is an exact n- tuple of eigenvalues of an appropriate perturbed multiparameter eigenvalue problem. Also we present various comparisons with unstructured backward error of an approximate n-tuple eigenpair and in the special case we find the work given in literatures for a non-singular multiparameter eigenvalue problems. We discuss the Pseudpspectra on singular two parameter unstructured eigenvalue problems and its some applications.

Karl Meerbergen
K.U.Leuven, Department of Computer Science

The solution of a nonlinear eigenvalue problem using polynomial eigenvalue solvers

Thursday, 25.08.2011, 12:00 - 12:30, Room to be filled in later by organizers

Polynomial eigenvalue problems are often solved by transforming them to a Companion-like form. This is a linear eigenvalue problem of larger size that can be solved by methods for linear eigenvalue problems. For the quadratic eigenvalue problem, this idea led to the SOAR and Q-Arnoldi methods. In this talk, we consider extensions of these methods for the solution of non-linear eigenvalue problems. The non-linear operator is approximated by a polynomial. The associated polynomial eigenvalue problem is then solved by the shift-and-invert Arnoldi method. The degree of the polynomial is not fixed beforehand but dynamically adapted and equal to the iteration number of the Arnoldi method. This allows for a flexible and automatic choice of the degree. We discuss various choices of polynomial approximations, stopping criteria and restarting strategies. The storage cost of the iteration vector is proportional to the square of the iteration count. We discuss techniques to reduce this cost.

This contribution is joint work with Elias Jarlebring and Wim Michiels (K.U.Leuven, Belgium).

Nicos Karcanias
Systems and Control Centre, School of Engineering and Mathematical Sciences, City University London

Polynomial Matrices, Approximate GCD and Control Theory

Friday, 26.08.2011, 10:30 - 11:00, Room to be filled in later by organizers

Polynomial matrices, Matrix Pencils and the Greatest Common Divisor (GCD) of a set of polynomials are essential tools that underpin many of the structural properties of Linear Systems and Control Theory. The paper reviews their role and uses the new notion of the approximate GCD in Linear Systems and Control Theory. We use exterior algebra and the Plucher embedding to associate polynomial multivectors to polynomial matrices and matrix pencils associated with system descriptions. The notions of approximate and optimal approximate zero polynomials of a polynomial matrix is introduced by deploying recent results on the approximate GCD of a set of polynomials and the exterior algebra representation of polynomial matrices. The results provide a characterization of the notion of an approximate matrix divisor of a polynomial matrix and introduce the approximate, or almost zeros of polynomial matrices define the notion of almost non-coprimeness of a polynomial matrix and introduce a framework for computing the distance of a system description from families of systems having properties, such as uncontrollability and unobservability. The computational framework is expressed as a distance problem in a projective space and provide a new characterization of approximate zeros and decoupling zeros of linear systems and their optimal versions.

Fernando De Terán
Universidad Carlos III de Madrid

Fiedler linearizations of matrix polynomials

Friday, 26.08.2011, 11:00 - 11:30, Room to be filled in later by organizers

Linearization of matrix polynomials is the standard way to address the Polynomial Eigenvalue Problem. The first and second (Frobenius) companion forms have been classically almost the only linearizations used in practice. However, they are not always satisfactory because, for instance, they do not preserve certain structures of matrix polynomials that appear frequently in applied problems. This is one of the motivations for the search of new linearizations. In the past few years, several new families of linearizations have been introduced. One of the most interesting ones is the family of *Fiedler pencils*, because of its attractive and useful features: (a) the pencils in this family can be constructed directly from the coefficients of the polynomial using a uniform template; (b) they are always strong linearizations, for every matrix polynomial (regular or singular); (c) eigenvectors, minimal basis and minimal indices can be easily recovered from those of any linearization of the family, and (d) this family is a source for structured linearizations. In this talk we give an overview of all these features.

This contribution is joint work with Froilán M. Dopico (Universidad Carlos III de Madrid, Spain) and D. Steven Mackey (Western Michigan University, USA).

Stavros Vologiannidis
Department of Mathematics, Aristotle University of Thessaloniki, Greece

Extended Fiedler linearizations and eigenvector recovery

Friday, 26.08.2011, 11:30 - 12:00, Room to be filled in later by organizers

On 2004 and 2006, Antoniou and Vologiannidis presented a new family of companion forms associated to a regular polynomial matrix $T(s)$ using products of permutations of n elementary matrices where n is the degree of the polynomial matrix, generalizing similar results presented by Fiedler in 2003 where the scalar case was considered. In this presentation, extending this family of Fiedler linearizations, we present a broader family of companion like linearizations, termed extended Fiedler linearizations, using products of up to $n(n-1)/2$ elementary matrices. We show that all Fiedler linearizations are included in this extended family. Under given conditions, the proposed linearizations can be shown to consist of block entries where the coefficients of the polynomial matrix appear intact. Finally we provide a method for the recovery of the eigenvectors of the original polynomial matrix given the corresponding eigenvectors of an extended Fiedler linearization.

This contribution is joint work with Efstathios Antoniou (Department of Sciences, Technological Educational Institute of Thessaloniki, Greece).

Ion Zaballa
University of Basque Country-Euskal Herriko Unibertsitatea

Eigenstructure of Real Symmetric Quadratic Matrix Polynomials

Friday, 26.08.2011, 12:00 - 12:30, Room to be filled in later by organizers

The eigenstructure of a real symmetric matrix polynomials is formed not only by its Jordan form but also by the sign characteristic associated to the Jordan blocks corresponding to real eigenvalues. In order to be able to solve the Inverse Eigenvalue Problem for real symmetric quadratic matrix polynomials, the allowable eigenstructure problem must be first considered. An orthogonality conditions, that the Jordan chains of any even degree real symmetric matrix polynomial must satisfied, will be shown to impose some restrictions on the allowable eigenstructures. Examples with doubtfull admissible eigestructure will be solved with the help of the developed theory.

This contribution is joint work with Peter Lancaster (University of Calgary, Alberta, Canada) and Uwe Prells.

MS5

Vadim Olshevsky and Raf Vandebril
Department of Mathematics, University of Connecticut, USA
Department of Computer Science, K.U.Leuven, Belgium

Quasi- and Semiseparable Matrices

Monday, 22.08.2011, and Thursday, 25.08.2011, 10:30 - 12:30

Roughly a decade ago, structured rank matrices, among which the quasi- and semiseparable matrices are the most popular ones, were gaining a lot of interest. At that time it emerged that not only exploiting sparsity but also low rank properties could lead to significant speed-up and enhanced accuracy. Initial research focused on efficient system solving for the most prominent members the quasi- and semiseparable matrices. Quickly thereafter, many researchers started investigating the applicability of these novel techniques. Not only did rank structured matrices found their way into a wide variety of algorithms and applications, but also the structure of the matrices was heavily subjected to changes. Nowadays there is an extensive list of specific classes of rank structured matrices, with for instance nested subblocks of low ranks. For many of these classes effective algorithms have been developed, capable of efficiently solving systems of equations, fast inversion, structure preserving QR-algorithms and so forth. Also theoretically intriguing links with orthogonal polynomials have been revealed.
In this minisymposium the latest developments with respect to structured rank matrices, both theoretically as practically will be presented.

Speakers

MS5.1: Quasi- and Semiseparable Matrices (PART I)		
Monday, 22.08.2011		**Room:**
10:30 - 11:00	**Luca Gemignani** *On the use of functional iteration methods for solving generalized eigenproblems*	p. 51
11:00 - 11:30	**Paola Boito** *Fast eigenvalue computation based on structured implicit QR with compression*	p. 51
11:30 - 12:00	**Raf Vandebril** *Chasing bulges or rotations? A new family of matrices admitting linear time QR-steps*	p. 52
12:00 - 12:30	**Vadim Olshevsky** *t.b.a.*	p. 52

MS5.2: Quasi- and Semiseparable Matrices (PART II)		
Thursday, 25.08.2011		**Room:**
10:30 - 11:00	**Gianna M. Del Corso** *An extension of the Faber Manteuffel Theorem*	p. 53
11:00 - 11:30	**Matthias Humet** *Algorithms to compute spectral transformations for orthogonal polynomials on the unit circle*	p. 53
11:30 - 12:00	**Pavel Zhlobich** *Stability of QR-based system solvers for a subclass of Quasiseparable Order One matrices*	p. 54
12:00 - 12:30	**Marc Van Barel** *Orthogonal functions and matrix computations*	p. 54

- end of talks -

Luca Gemignani
Department of Mathematics, University of Pisa, Pisa, Italy

On the use of functional iteration methods for solving generalized eigenproblems

Monday, 22.08.2011, 10:30 - 11:00, Room to be filled in later by organizers

In this talk we discuss the use of the Ehrlich-Aberth method for solving generalized eigenproblems, and describe the results of our computational experience. It is shown that the method can be implemented in an efficient and numerically robust way by using the rank structure of the associated linearizations.

This contribution is joint work with Vanni Noferini (University of Pisa).

Paola Boito
XLIM - University of Limoges

Fast eigenvalue computation based on structured implicit QR with compression

Monday, 22.08.2011, 11:00 - 11:30, Room to be filled in later by organizers

We present a fast structured version of the implicit QR method for eigenvalue computation that can be applied to a class of structured matrices. This class consists of Hessenberg matrices that are rank-one perturbations of unitary matrices and includes, in particular, companion (Frobenius) matrices.
A structured eigensolver based on implicit QR and designed for the same class of structured matrices was also proposed in a previous paper [Bini, Boito, Eidelman, Gemignani, Gohberg, 'A fast implicit QR eigenvalue algorithm for companion matrices', LAA 2010]. Both methods have (asymptotic) quadratic complexity with respect to matrix size. In this new version of structured implicit QR we avoid explicit computation of a unitary factorization of the matrix. Instead, we rely mainly on the computation of quasiseparable generators. A compression step is then performed in order to obtain generators of minimum order.
While the asymptotic complexity does not change, this approach requires less floating-point operations and allows to improve running times. Numerical results and comparisons will be presented.

This contribution is joint work with Yuli Eidelman and Israel Gohberg (University of Tel-Aviv).

Raf Vandebril
Katholieke Universiteit Leuven, Belgium

Chasing bulges or rotations? A new family of matrices admitting linear time QR-steps

Monday, 22.08.2011, 11:30 - 12:00, Room to be filled in later by organizers

The QR-algorithm is a renowned method for computing all eigenvalues of an arbitrary matrix. A preliminary unitary similarity transformation to Hessenberg form is indispensable for keeping the computational complexity of the subsequent QR-steps under control. In this talk, a new family of matrices, sharing the major qualities of Hessenberg matrices, will be put forward.
We will benefit from the QR-factorization of the matrices involved. The prescribed order of rotations in the decomposition of the Q-factor uniquely characterizes several matrix types such as, e.g., Hessenberg, inverse Hessenberg and CMV matrices. We wil loosen this fixed rotational ordering and establish implicit QR-type algorithms for these matrices requires diverse concepts: a preliminary unitary similarity transformation; the uniqueness of this reduction; an explicit and implicit QR-type algorithm and; pursuing rotations instead of bulges. The numerical experiments show comparable accuracy for a wide variety of matrix types, but discloses an intriguing difference between the average number of necessary QR-steps.

This contribution is joint work with David Watkins (Washington State University, USA).

Vadim Olshevsky
t.b.a.

t.b.a.

Monday, 22.08.2011, 12:00 - 12:30, Room to be filled in later by organizers

t. b. a.

Gianna M. Del Corso
Dipartimento di Informatica, University of Pisa, Italy

An extension of the Faber Manteuffel Theorem

Thursday, 25.08.2011, 10:30 - 11:00, Room to be filled in later by organizers

Recently there has been much interest around matrices whose structure can be maintained under QR steps. In fact, most of the time it is possible to take advantage from the structure, designing QR algorithms with a linear cost per step. Quasiseparable and semiseparable matrices are among them as well as the Hessenberg form of hermitian plus low rank matrices. Inspired by those examples we try to understand which class of matrices once reduced to Hessenberg form has a semiseparable structure in the upper right corner, that is, can be written as the sum of a banded Hessenberg matrix plus the upper triangular part of a semiseparable matrix.
In 1984 Faber and Manteuffel proved that the only matrices that can be reduced to Hessenberg form with an upper banded structure which is maintained under QR steps are the normal matrices, that is matrices such that $A^H = p_s(A)$ where $p_s(\cdot)$ is a polynomial with degree at most s. In the nonderogatory case, we extend this result giving necessary and sufficient condition for a matrix to be reducible to Hessenberg form with a rank k semiseparable structure above the s-th superdiagonal. The matrices in this class are such that $A^H - C_k = q_s(A)$, where $q_s(\cdot)$ is a polynomial of degree s and C_k is a rank k matrix.
This contribution is joint work with Roberto Bevilacqua (University of Pisa, Italy).

Matthias Humet
Department of computer science, K.U.Leuven, Belgium

Algorithms to compute spectral transformations for orthogonal polynomials on the unit circle

Thursday, 25.08.2011, 11:00 - 11:30, Room to be filled in later by organizers

Let $L(p,q)$ be a positive definite bilinear functional on the unit circle, then there exists a sequence of polynomials of ascending degree, orthonormal with respect to L. This sequence satisfies recurrence relations which are determined completely by a sequence of complex numbers inside the unit circle, called Schur parameters. We consider the spectral transformation $\hat{L}(p,q) = L((z-\alpha)p,(z-\alpha)q)$, for $|\alpha| > 1$, called the Christoffel transformation of L. of L for $|\alpha| > 1$. The Schur parameters associated with $\hat{L}$ can be computed efficiently from those of L. This involves a QR-step with shift α for a unitary Hessenberg matrix of order n, which can be described by n Schur parameters. Our main contribution involves the inverse problem: given $\hat{L}$, the above expression defines the Geronimus transformation L of $\hat{L}$. We have devised a forward and a backward algorithm to efficiently compute the Schur parameters associated with L from those of $\hat{L}$. Both algorithms are based on an RQ-factorization and r equire one free parameter. We compare the accuracy of both algorithms using numerical experiments and explain their remarkable behaviour by means of a third spectral transformation which is linked to the former two: the Uvarov transformation, defined by $U(p,q) = L(p,q) + m\,p(\alpha)\,\overline{q}(1/\alpha) + m\,p(1/\overline{\alpha})\,\overline{q}(\overline{\alpha})$.
This contribution is joint work with Marc Van Barel (K.U.Leuven, Belgium).

Pavel Zhlobich
School of Mathematics, University of Edinburgh

Stability of QR-based system solvers for a subclass of Quasiseparable Order One matrices

Thursday, 25.08.2011, 11:30 - 12:00, Room to be filled in later by organizers

The development of fast algorithms to perform computations with quasiseparable matrices has received a lot of attention in the last decade. Many different algorithms have been presented by several research groups all over the world. Despite of this intense activity, there is no any rounding error analysis published for these fast algorithms, as far as we know. We present error analyses for two fast solvers of quasiseparable linear systems when they are applied on order one quasiseparable matrices that include the diagonal in the lower (or in the upper) triangular part. This analysis requires novel structured techniques and proves rigorously that only one of the considered algorithms is backward stable, while the other one is not.

This contribution is joint work with Froilán Dopico (Universidad Carlos III de Madrid, Spain) and Vadim Olshevsky (University of Connecticut, USA).

Marc Van Barel
Department of Computer Science, Katholieke Universiteit Leuven, Belgium

Orthogonal functions and matrix computations

Thursday, 25.08.2011, 12:00 - 12:30, Room to be filled in later by organizers

Orthogonal polynomials on the real line satisfy a three term recurrence relation. This relation can be written in matrix notation by using a tridiagonal matrix. Similarly, orthogonal polynomials on the unit circle satisfy a Szegő recurrence relation that corresponds to an (almost) unitary Hessenberg matrix. It turns out that orthogonal rational functions with prescribed poles satisfy a recurrence relation that corresponds to diagonal plus semiseparable matrices. This leads to efficient algorithms for computing the recurrence parameters for these orthogonal rational functions by solving corresponding linear algebra problems. In this talk we will study several of these connections between orthogonal functions and matrix computations and give some numerical examples illustrating the numerical behaviour of these algorithms.

MS6

Holger Rauhut and Gitta Kutyniok
University of Bonn, University of Osnabrück

Compressed Sensing and Sparse Approximation Algorithms

Thursday, 25.08.2011, and Friday, 26.08.2011, 10:30 - 12:30

The field of sparse approximation is concerned with the problem of representing a target vector using a short linear combination of vectors drawn from a large, fixed collection called a dictionary. The earliest applications arose in approximation theory for functions and operators. A closely related classical problem is variable selection in regression. Modern applications include machine learning, signal and image processing, and numerical analysis. Although sparse approximation is computationally hard in the general case, contemporary research has identified situations where tractable algorithms can provably solve sparse approximation problems. Some of the most interesting recent advances concern dictionary learning and sparse approximation of random signals.

Compressed sensing sensing is a recent field which has seen enormous interest and growth. Quite surprisingly, it predicts that sparse high-dimensional signals can be recovered efficiently from what was previously considered highly incomplete measurements. This discovery has led to a fundamentally new approach to certain signal and image recovery problems. Remarkably, mainly random constructions for good measurement matrices are known so far. Efficient reconstruction schemes include convex optimization strategies, such as ℓ_1-minimization, as well as greedy algorithms.

Closely related to compressed is the rank minimization problem which has its roots in image compression algorithms, learning theory, and collaborative filtering. In a nutshell, collaborative filtering is the task of making automatic predictions about the interests of a user by collecting taste information from many users. A simple mathematical model for this setup can be described by the matrix completion problem where one has only a few observations of the entries of a low-rank matrix and tries to complete the missing entries. More generally, one may consider the problem of minimizing the rank of a matrix subject to some general linear constraint. Convex relaxation strategies such as nuclear norm minimization and semidefinite programming apply to its solution. It turns out, that the analysis of low rank recovery is analog to the one of compressed sensing, and again, random maps provide optimal measurements.

The minisymposium will focus around recent results on compressed sensing, dictionary learning and low rank recovery, as well as corresponding efficient algorithms.

Speakers

Thursday, 25.08.2011	**MS6.1: Compressed Sensing and Sparse Approximation Algorithms (PART I)**	**Room:**
10:30 - 11:00	**Mark A. Iwen** *Compressed Sensing for Manifold Data*	p. 57
11:00 - 11:30	**Felix Krahmer** *New and Improved Johnson-Lindenstrauss Embeddings via the Restricted Isometry Property*	p. 57
11:30 - 12:00	**Gitta Kutyniok** *Separation of Data by Sparse Approximations*	p. 58
12:00 - 12:30	**Götz E. Pfander** *From the Bourgain Tzafriri Restricted Invertibility Theorem to restricted isometries*	p. 58

Friday, 26.08.2011	**MS6.2: Compressed Sensing and Sparse Approximation Algorithms (PART II)**	**Room:**
10:30 - 11:00	**Holger Rauhut** *Compressive Sensing and Structured Random Matrices*	p. 59
11:00 - 11:30	**John Wright** *Local Correctness of Dictionary Learning Algorithms*	p. 59
11:30 - 12:00	**t.b.a** *t.b.a*	p. 60
12:00 - 12:30	**t.b.a** *t.b.a*	p. 60

- end of session -

Mark A. Iwen
Duke University

Compressed Sensing for Manifold Data

Thursday, 25.08.2011, 10:30 - 11:00, Room to be filled in later by organizers

Preliminary work involving the recovery of manifold data using compressive measurements will be discussed, along with related sampling bounds for the approximation of manifold data via a recent multiscale piecewise linear approximation method known as "Geometric Wavelets" [Allard, Chen, Maggioni, *Multiscale Geometric Methods for Data Sets II: Geometric Wavelets*, Submitted, 2011].
This contribution is joint work with Mauro Maggioni (Duke University, USA).

Felix Krahmer
Universität Bonn, Germany

New and Improved Johnson-Lindenstrauss Embeddings via the Restricted Isometry Property

Thursday, 25.08.2011, 11:00 - 11:30, Room to be filled in later by organizers

The Johnson-Lindenstrauss (JL) Lemma states that any set of p points in high dimensional Euclidean space can be embedded into $O(\delta^{-2}\log(p))$ dimensions, without distorting the distance between any two points by more than a factor between $1-\delta$ and $1+\delta$. We establish a new connection between the JL Lemma and the Restricted Isometry Property (RIP), a well-known concept in the theory of sparse recovery often used for showing the success of ℓ_1-minimization.
Consider an $m \times N$ matrix satisfying the (k,δ_k)-RIP and an arbitrary set E of $O(e^k)$ points in $\mathbf{R}^N$. We show that with high probability, such a matrix with randomized column signs maps E into $\mathbf{R}^m$ without distorting the distance between any two points by more than a factor of $1 \pm 4\delta_k$. Consequently, matrices satisfying the Restricted Isometry of optimal order provide optimal Johnson-Lindenstrauss embeddings up to a logarithmic factor in N. Moreover, our results yield the best known bounds on the necessary embedding dimension m for a wide class of structured random matrices. Our results also have a direct application in the area of compressed sensing for redundant dictionaries.

This contribution is joint work with Rachel Ward (Courant Institute, NYU, USA).

Gitta Kutyniok
Universität Osnabrück

Separation of Data by Sparse Approximations

Thursday, 25.08.2011, 11:30 - 12:00, Room to be filled in later by organizers

Modern data is customarily of multimodal nature, and analysis tasks typically require separation into the single components. Although a highly ill-posed problem, the morphological difference of these components often allows a precise separation. A novel methodology consists in applying ℓ_1 minimization to a composed dictionary consisting of tight frames each sparsifying one of the components.
In this talk, we will first discuss a very general approach to derive estimates on the accuracy of separation using cluster coherence and clustered/geometric sparsity. Then we will use these results to analyze performance of this methodology for separation of image components.

This contribution is joint work with David Donoho (Stanford University).

Götz E. Pfander
Jacobs University Bremen

From the Bourgain Tzafriri Restricted Invertibility Theorem to restricted isometries

Thursday, 25.08.2011, 12:00 - 12:30, Room to be filled in later by organizers

The Bourgain-Tzafriri Restricted Invertibility Theorem states conditions under which a Riesz bases (for its span) can be extracted from a given system of norm one vectors in finite dimensional spaces. The challenge is to choose a large subset while making sure that the resulting lower Riesz bound remains large. An upper Riesz bound of the selected Riesz bases is inherited from the frame bound of the original system of vectors.
In this talk, we shall present an algorithm that allows us to control both, the lower and the upper, Riesz bounds.
This contribution is joint work with Pete Casazza (University of Missouri,USA).

Holger Rauhut
Hausdorff Center for Mathematics & Institute for Numerical Simulation
University of Bonn

Compressive Sensing and Structured Random Matrices

Friday, 26.08.2011, 10:30 - 11:00, Room to be filled in later by organizers

Compressive sensing is a recent paradigm in signal processing and sampling theory that predicts that sparse signals can be recovered from a small number of linear and non-adaptive measurements using convex optimization or greedy algorithms. Quite remarkably, all good constructions of the so called measurement matrix known so far are based on randomness. While Gaussian random matrices provide optimal recovery guarantees, such unstructured matrices are of limited use in applications. Indeed, structure often allows to have fast matrix vector multiplies. This is crucial in order to speed up recovery algorithms and to deal with large scale problems. The talk discusses models of structured random matrices that are useful in certain applications, and presents corresponding recovery guarantees. An important type of structured random matrix arises in connection with sampling sparse expansions in terms of bounded orthogonal systems (such as the Fourier system). The second type of structured random matrices to be discussed are partial random circulant matrices, that is, from convolution. In particular, we present recent results with J. Romberg and J. Tropp on the restricted isometry property of such matrices.
This contribution is joint work with Justin Romberg (Georgia Insitute of Technology, USA) and Joel Tropp (California Institute of Technology, USA).

John Wright
Microsoft Research

Local Correctness of Dictionary Learning Algorithms

Friday, 26.08.2011, 11:00 - 11:30, Room to be filled in later by organizers

The idea that many important classes of signals can be well-represented by linear combinations of a small set of atoms selected from a given dictionary has had dramatic impact on the theory and practice of signal processing. For practical problems in which an appropriate sparsifying dictionary is not known ahead of time, a very popular and successful heuristic is to search for a dictionary that minimizes an appropriate sparsity surrogate over a given set of sample data. In this talk, we describe steps towards understanding when this problem can be solved by efficient algorithms. We show that under mild hypotheses, the dictionary learning problem is locally well-posed: the desired solution is a local minimum of the ℓ^1 norm. Namely, if $A \in R^{m\times n}$ is an incoherent (and possibly overcomplete) dictionary, and the coefficients $X \in R^{n\times p}$ follow a random sparse model, then with high probability (A, X) is a local minimum of the ℓ^1 norm over the manifold of factorizations (A', X') satisfying $A'X' = Y$, provided the number of samples $p = \Omega(n^3 k)$. For overcomplete A, this is the first result showing that the dictionary learning problem is locally solvable.

This contribution is joint work with Quan Geng (University of Illinois at Urbana-Champaign) and Huan Wang (Yale University).

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Friday, 26.08.2011, 11:30 - 12:00, Room to be filled in later by organizers

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Friday, 26.08.2011, 12:00 - 12:30, Room to be filled in later by organizers

t. b. a.

YR1

Joscha Gedicke and Agnieszka Miedlar
Humboldt-Universität zu Berlin, Technische Universität Berlin

Modern methods for PDE eigenvalue problems

Wednesday, 24.08.2011, 10:30 - 12:30

Since decades modern technological applications lead to challenging PDE eigenvalue problems, e.g., vibrations of structures, modeling of photonic gap materials, analysis of the hydrodynamic stability, or calculations of energy levels in quantum mechanics, which involve research in many different areas of mathematics. The goal of the minisymposium is to present the state of the art in the area of PDE eigenvalue problems with particular emphasis on interdependence between numerical linear algebra techniques and numerical treatment of partial differential equations, e.g., a better understanding of the interplay between the approximation error arising from the iterative algebraic solver and the discretization error from the numerical treatment of the PDE is needed.

Practical applications leading to linear and nonlinear (or polynomial) PDE eigenvalue problems will be discussed. The rich variety of talks will cover both the theoretical origins as well as current algorithmic techniques. Recent developments such as adaptive finite element methods (AFEM), a priori and a posteriori error estimates, convergence theory for eigensolvers, preconditioned and multilevel techniques will be introduced.
The purpose of this minisymposium is to bring together researchers who work in the area of PDE eigenvalue problems but represent different research communities with various research priorities. Due to the large variety of applications and contributions (influences) from several branches of mathematics, with this minisymposium, we want to stress the need for interdisciplinary research.

Speakers

YR1: Modern methods for PDE eigenvalue problems		
Wednesday, 24.08.2011		**Room:**
10:30 - 10:50	**Cedric Effenberger**	
	Projection methods for a class of nonlinear PDE eigenvalue problems	p. 63
10:50 - 11:10	**Joscha Gedicke**	
	An Optimal Eigenvalue Solver	p. 63
11:10 - 11:30	**Stefano Giani**	
	Goal-oriented hp-Adaptive Discontinuous Galerkin Finite Element Methods for Elliptic Eigenvalue Problems	p. 64
11:30 - 11:50	**Bärbel Janssen**	
	Solution of large-scale PDE-eigenvalue problems	p. 64
11:50 - 12:10	**Dominik Löchel**	
	A multilevel Jacobi-Davidson method for parameter dependent PDE eigenvalue problems	p. 65
12:10 - 12:30	**Agnieszka Miedlar**	
	Inexact Adaptive Finite Element computations of PDE eigenvalue problems	p. 65

- end of session -

Cedric Effenberger
Seminar for Applied Mathematics, ETH Zurich, Switzerland

Projection methods for a class of nonlinear PDE eigenvalue problems

Wednesday, 24.08.2011, 10:30 - 10:50, Room to be filled in later by organizers

The solution of PDE eigenvalue problems often involves several projection steps. First, the infinite-dimensional problem is discretized, for example, by projecting it onto a (finite-dimensional) finite element space via a Galerkin approach. Since the resulting matrix eigenvalue problems are typically large and sparse, they are usually again solved by means of projection methods, such as the Arnoldi or Jacobi-Davidson algorithm.
The whole procedure is motivated by the expectation that the eigenvalues of the projected problems will be good approximations to some of the eigenvalues of the original problem. For linear eigenvalue problems, this expectation is backed by a range of theoretical results. However, a variety of applications gives rise to more general (PDE) eigenvalue problems which are nonlinear in the eigenvalue parameter. In this talk, we study the effect of projections on such nonlinear eigenvalue problems.

This contribution is joint work with Daniel Kressner (EPF Lausanne, Switzerland).

Joscha Gedicke
Humboldt-Universität zu Berlin, Germany

An Optimal Eigenvalue Solver

Wednesday, 24.08.2011, 10:50 - 11:10, Room to be filled in later by organizers

This talk presents the optimal computational complexity of a combined adaptive finite element method (AFEM) with an iterative algebraic eigenvalue solver for a simple symmetric model problem. The analysis is based on a direct approach for eigenvalue problems and allows the use of higher order conforming finite element spaces with fixed polynomial degree. First the quasi-optimal convergence for the eigenvalue problem under the usual assumption that the sub-problems are solved exactly is shown. As for the source problem the convergence analysis for the quasi error does not need the inner node property. These results are relaxed to the inexact approximations of some iterative eigenvalue solver and thus lead to a combined AFEM and iterative eigenvalue solver algorithm. The proposed optimal algorithm involves a proper termination criterion for the iterative algebraic eigenvalue solver and does not need any coarsening. Numerical examples show optimal computational complexity.

This contribution is joint work with Carsten Carstensen (HU Berlin, Germany).

Stefano Giani
University of Nottingham

Goal-oriented hp-Adaptive Discontinuous Galerkin Finite Element Methods for Elliptic Eigenvalue Problems

Wednesday, 24.08.2011, 11:10 - 11:30, Room to be filled in later by organizers

A discontinuous Galerkin method, with hp-adaptivity based on the approximate solution of appropriate dual problems, is employed for highly-accurate eigenvalue computations on a collection of benchmark examples with interesting features like discontinuous coefficients and non-convex geometries. The most remarkable advantage of the goal-oriented approach is an effectivity index for eigenvalues very close to one on the all sequence of hp-adaptively refined meshes.
The hp-adaptivity algorithm, that we present, automatically adapts locally in either h or p exploiting an estimation of the local smoothness of the computed eigenfunction. This ensures an exponential convergence rate for all considered examples.

This contribution is joint work with Luka Grubišić (University of Zagreb, Croatia) and Jeffrey S. Ovall (University of Kentucky, USA).

Bärbel Janssen
Ruprecht-Karls-Universität Heidelberg, Germany

Solution of large-scale PDE-eigenvalue problems

Wednesday, 24.08.2011, 11:30 - 11:50, Room to be filled in later by organizers

The solution of large eigenvalue problems is inefficient with software packages such as Matlab. In this talk we present numerical methods based on an open source finite element library called deal.II. A novel interface to ARPACK was added to deal.II. This implementation allows for the utilization of all the functionalities that are provided by this library such as adaptive refinement and a variety of finite elements.
An important issue for solving large-scale eigenvalue problems is a suitable preconditioner. We present a geometric multilevel preconditioner on continuous finite elements. This preconditioner works on meshes with hanging nodes and smoothing is done locally.
We show numerical results on locally refined meshes using the estimator proposed in [V. Mehrmann and A. Miedlar, Adaptive solution of elliptic PDE-eigenvalue problems. Part I: Eigenvalues, MATHEON Preprint 565, February 2009].

Dominik Löchel
Karlsruhe Institute of Technology (KIT)

A multilevel Jacobi-Davidson method for parameter dependent PDE eigenvalue problems

Wednesday, 24.08.2011, 11:50 - 12:10, Room to be filled in later by organizers

The selfconsistent modelling of energy losses in a Tokamak leads to a partial differential eigenvalue equation (PDEE) with parameter dependent coefficients. For each parameter up to three physically relevant eigenpairs are required. The challenge is to find the desired eigenpairs up to a sufficient level of accuracy with low computational cost as the PDEE is only one part of an outer iteration procedure.

After discretization, the PDEE becomes a rational or cubic eigenvalue equation. We use a variation of the Jacobi-Davidson (JD) method. Carefully selected discretization methods improve the level of accuracy per computational cost. Additionally the JD process is accelerated by a multilevel strategy. This allows for an almost optimal scaling. Furthermore, the simultaneous computation of the left and right eigenvector reduces the number of JD cycles needed to achieve a certain level of accuracy and enables us to estimate the error. A similarity measure is defined on the eigenvalues and the eigenfunctions to detect the propper eigenpairs, especially when the parameter is shifted.

Agnieszka Miedlar
Technische Universität Berlin, Germany

Inexact Adaptive Finite Element computations of PDE eigenvalue problems

Wednesday, 24.08.2011, 12:10 - 12:30, Room to be filled in later by organizers

With help of a standard residual-type a posteriori error estimator $\eta(\lambda_h, u_h)$ and a discrete equivalence of the norm of the residual in the dual space $H^{-1}(\Omega)$ proposed in [U. Hetmaniuk and R. Lehoucq, *Uniform accuracy of eigenpairs from a shift-invert Lanczos method*, SIAM J. Matrix Anal. Appl., Vol. 28, pp. 927-948 (2006)] we introduce a combined a posteriori error estimator for a global error in the $H^1(\Omega)$-norm and design a balanced AFEM algorithm which significantly reduces the number of eigensolver iterations.
Several numerical examples will be presented to illustrate the performance of the algorithm. A proper equilibration between the discretization and iteration error will be discussed to derive an efficient stopping criteria for the iterative eigensolver.

This contribution is joint work with Volker Mehrmann (TU Berlin, Germany).

YR2

Fernando de Terán and Marta Peña
Universidad Carlos III de Madrid, Spain and Universitat Politècnica de Catalunya, Spain

The theory of orbits in numerical linear algebra and control theory

Tuesday, 23.08.2011, 10:30 - 12:30

Matrices and matrix pencils appear in a wide variety of applied problems mostly related with linear systems of ordinary differential equations. In this context, the invariants of the matrix or the matrix pencil contain relevant information on the behaviour of the solution of the system. These invariants depend on the kind of transformation we consider. For instance, in matrices it is usual to deal with the relation of similarity, though in several problems the appropriate relation is the congruence one. In matrix pencils the typical relation is strict equivalence and, in the particular case of linear systems with control, the feedback equivalence is considered. Associated with these relations there exist canonical forms comprising the appropriate invariants of the system. The computation of these canonical forms is a difficult task due to the presence of arbitrarily close different structures. The theory of orbits provides a geometric framework to the theory of canonical forms and, in particular, to the problem of computing these forms. The knowledge of the orbit space is a useful tool in explaining eventual failures of the existing algorithms and in the design of new algorithms for the computation of canonical forms. In the early 70's, Arnold introduced the similarity orbits to examine the nearby structures to a given Jordan canonical form. Arnold's ideas have been recovered by several authors (mostly since the 90's), and they have been applied well to matrix pencils and linear systems. Thanks to the work of these researchers, nowadays we have a detailed knowledge of the space of canonical forms of matrices (under similarity) and matrix pencils (under strict equivalence). We know not only the generic structures and all the nearby structures to a given one, but also the inclusion relationship between the closures of different structures and their complete stratification. In the context of control theory, the same can be said about the orbit space (under feedback equivalence) for pairs of linear time-invariant systems. However, in some situations it is important to restrict oneself to a certain set of matrices, matrix pencils or linear systems. In these cases, the problem of determining the nearby structures within this specific set makes sense and it is an open area of research. This has been done, for instance, for matrix pencils with fixed rank. The theory of orbits is still an open field of research in the link between geometry and numerical analysis. In the context of numerical linear algebra and control, there is variety of interesting open problems and lines of research where this theory can be useful. For instance, in the study of other kind of relations (congruency of matrices and matrix pencils, single or combined action of feedbacks, change of state and input variables in linear systems), other matrix constructions (matrix polynomials, generalized matrix products) or particular kinds of matrix pencils or linear systems (palindromic or symmetric pencils, non-controllable bimodal systems). The aim of this minisymposium is to present some of these lines of current and future research, together with recent results within them.

Speakers

	YR2: The theory of orbits in numerical linear algebra and control theory	
Tuesday, 23.08.2011		**Room:**
10:30 - 11:00	**Stefan Johansson**	
	The closure hierarchy of full rank polynomial matrices	p. 68
11:00 - 11:30	**Fernando De Terán**	
	The solution of the equation $XA + AX^T = 0$ *and its application to the theory of orbits*	p. 68
11:30 - 12:00	**Marta Peña**	
	Orbit stratification of non-controllable bimodal systems	p. 69
12:00 - 12:30	**Carmen Ortiz**	
	Geometric structure of the orbits of a controllable pair	p. 69

- end of session -

Stefan Johansson
Department of Computing Science, Umeå University, Sweden

The closure hierarchy of full rank polynomial matrices

Tuesday, 23.08.2011, 10:30 - 11:00, Room to be filled in later by organizers

We study how canonical forms of polynomial matrices $P(s) := P_d s^d + \ldots + P_1 s + P_0$, where $P_i \in \mathbf{C}^{m \times n}$, behave under small perturbations. The objective is to understand how small variations of the coefficients P_i can change a (computed) canonical structure of $P(s)$. Our approach to such an analysis is to study structured perturbations of polynomial matrix linearizations. One tool that can be used to analyze the qualitative information of nearby matrix pencils is the theory of stratification as introduced by Edelman, Elmroth, and Kågström. A stratification reveals the closure hierarchy of orbits or bundles of nearby canonical structures and gives important qualitative information about an underlying dynamical system. We extend the theory of stratification for matrix pencils and matrix pairs to polynomial matrices by making use of appropriate linearizations (first and second companion forms). We show that the stratification rules for linearizations of full normal rank ($= m$ or n) polynomial matrices $P(s)$ are a subset of the rules for controllability pairs (A, B) associated with linear time-invariant systems.

This contribution is joint work with Bo Kågström (Umeå University, Sweden) and Paul Van Dooren (Université catholique de Louvain, Belgium).

Fernando De Terán
Universidad Carlos III de Madrid, Spain

The solution of the equation $XA + AX^T = 0$ and its application to the theory of orbits

Tuesday, 23.08.2011, 11:00 - 11:30, Room to be filled in later by organizers

We describe how to find the general solution of the matrix equation $XA + AX^T = 0$, where A is a given $n \times n$ matrix with complex entries. The procedure followed to solve this equation allows us to determine the dimension of its solution space in terms of the canonical form for congruence of A. This result has immediate applications in the theory of congruence orbits of $n \times n$ matrices, because the set

$$\{XA + AX^T : X \text{ an } n \times n \text{ matrix with complex entries}\}$$

is the tangent space at A of the congruence orbit of A. Hence, the codimension of this orbit is precisely the dimension of the solution space of $XA + AX^T = 0$. As a consequence, we are able to determine the generic canonical structure of matrices under the action of congruence. If time permits, we will also show how this can be easily extended to the theory of palindromic matrix pencils, which have attracted recently the interest of researchers in numerical linear algebra. In particular, we will show also the generic Kronecker structure of this kind of matrix pencils.

This contribution is joint work with Froilán M. Dopico (Universidad Carlos III de Madrid, Spain).

Marta Peña
Universitat Politecnica de Catalunya, Spain

Orbit stratification of non-controllable bimodal systems

Tuesday, 23.08.2011, 11:30 - 12:00, Room to be filled in later by organizers

Being the controllable bimodal systems an open set, its border is not a manifold, in general. So, it seems natural to ask for stratifying it, that is, the non-controllable bimodal systems. We start from the orbit stratification of all bimodal systems, and we use reduced representatives of each stratum in order to obtain the subset of non-controllable ones.

This contribution is joint work with Josep Ferrer (Universitat Politecnica de Catalunya, Spain) and Dolors Magret (Universitat Politecnica de Catalunya, Spain).

Carmen Ortiz
Universidad de Extremadura, Spain

Geometric structure of the orbits of a controllable pair

Tuesday, 23.08.2011, 12:00 - 12:30, Room to be filled in later by organizers

Given a pair of matrices representing a controllable linear system, we study its orbits (or equivalence classes) by the single or combined action of feedbacks and change of state and input variables, as well as their intersections. In particular, one proves that they are differentiable manifolds and one computes their dimensions when the given pair is in the Brunovsky-Kronecker reduced form.

This contribution is joint work with Albert Compta (Universitat Politecnica de Catalunya, Spain), Josep Ferrer (Universitat Politecnica de Catalunya, Spain) and Marta Peña (Universitat Politecnica de Catalunya, Spain).

YR3

Minerva Catral and Amy Wangsness Wehe
Xavier University and Fitchburg State University

Combinatorial Matrix Theory

Tuesday, 23.08.2011, 10:30 - 12:30

In this minisymposium, speakers will present new results and recent developments in using linear algebra and graph theory to solve problems arising from the combinatorial structure of matrices described by graphs and digraphs. Combinatorial matrix theory is an exciting subject area that has seen much growth in recent years, having applications in economics, biology, chemistry, sociology and other disciplines. The minisymposium will highlight recent work of early career researchers and graduate students on topics such as minimum rank problems, sign patterns of some positivity classes of matrices and graphical descriptions of generalized inverses of certain bipartite matrices.

Speakers

YR3: Combinatorial Matrix Theory		
Tuesday, 23.08.2011		**Room:**
10:30 - 11:00	**Craig Erickson** *Potentially eventually positive and potentially eventually exponentially positive sign patterns*	p. 72
11:00 - 11:30	**Michael Young** *Zero Forcing Sets with Applications*	p. 72
11:30 - 12:00	**Minerva Catral** *Drazin and Group Inverses of Matrices with Certain Bipartite Digraphs*	p. 73
12:00 - 12:30	**Amy Wangsness Wehe** *Discussions on when $mr^{-}(G) = MR^{-}(G)$ in Skew Symmetric Matrices*	p. 73

- end of session -

Craig Erickson
Iowa State University, USA

Potentially eventually positive and potentially eventually exponentially positive sign patterns

Tuesday, 23.08.2011, 10:30 - 11:00, Room to be filled in later by organizers

A real square matrix A is eventually positive if there exists a positive real number k_0 such that for all $k \geq k_0$, $A^k > 0$ (where the inequality is entrywise). Matrix A is eventually exponentially positive if there exists a positive real number t_0 such that for all $t \geq t_0$, e^{tA} is a positive matrix where $e^{tA} = \sum_{k=0}^{\infty} \frac{t^k A^k}{k!}$. A sign pattern is a matrix having entries in $\{+, -, 0\}$. A sign pattern $\mathcal{A}$ is potentially eventually exponentially positive (PEEP) (resp. potentially eventually positive) if there exists a matrix A, whose entries have signs equal to the entries in $\mathcal{A}$, such that A is eventually exponentially positive (resp. eventually positive). In this talk, some results on PEEP sign patterns are discussed and a classification of all 2x2 and 3x3 PEEP sign patterns is given.
This contribution is joint work with Marie Archer (Columbia College, USA), Minerva Catral (Xavier University, USA), Rana Haber (California State Polytechnic University, USA), Leslie Hogben (Iowa State University & American Institute of Mathematics, USA), Xavier Martinez-Rivera (University of Puerto Rico, USA), and Antonio Ochoa (California State Polytechnic University, USA).

Michael Young
Iowa State University

Zero Forcing Sets with Applications

Tuesday, 23.08.2011, 11:00 - 11:30, Room to be filled in later by organizers

Zero Forcing is a type of graph propopagation. The zero forcing number $Z(G)$ is the minimum number of vertices in a zero forcing set of a graph G. This graph parameter is used to study maximum nullity/minimum rank problems. This talk will desccuss the zero forcing number, the positive semidefinite zero forcing number, and their connection to control of quantum systems.

Minerva Catral
Xavier University, USA

Drazin and Group Inverses of Matrices with Certain Bipartite Digraphs

Tuesday, 23.08.2011, 11:30 - 12:00, Room to be filled in later by organizers

We consider block matrices whose digraphs are bipartite and present a simple block formula for their Drazin inverse. This form is used to derive a graph-theoretic description of the entries of the group inverse of some examples of such matrices, including those corresponding to broom graphs. If the group inverse of a nonnegative matrix corresponding to a broom graph exists, then it is shown that this group inverse is signed. An open question about group inverses of matrices having more general bipartite digraphs is posed and a summary of cases for which its answer is known is given.

This contribution is joint work with Dale Olesky (University of Victoria, Canada) and Pauline van den Driessche (University of Victoria, Canada).

Amy Wangsness Wehe
Fitchburg State University

Discussions on when $mr^-(G) = MR^-(G)$ in Skew Symmetric Matrices

Tuesday, 23.08.2011, 12:00 - 12:30, Room to be filled in later by organizers

This talk will explore the question of when $mr^-(G) = MR^-(G)$ in skew symmetric matrices. In particular, the talk will show some results toward answering this question and will also give insight into the process used in finding these results.

This contribution is joint work with Luz Maria DeAlba (Drake University) and Judith J McDonald (Washington State University).

YR4

Frederico Poloni and Timo Reis
Scuola Normale Superiore Pisa, Italy and TU Berlin, Germany
Hamburg University of Technology, Hamburg, Germany

Numerical methods for the solution of algebraic Riccati equations

Tuesday, 23.08.2011, 10:30 - 12:30

Algebraic Riccati Equations (AREs) are a kind of matrix equations widely studied in control theory and linear algebra. They arise for instance in linear-quadratic optimal control as well as model reduction of dynamical systems, both in the continuous- and discrete-time version

$$\begin{aligned} 0 &= Q + A^T X + XA - XGX, \\ 0 &= A^T XA - X - (A^T XB + S)(R + B^T XB)^{-1}(B^T XA + S^T) + Q, \end{aligned}$$

which are formally very different but similar from a theoretical and numerical point of view. Besides their central role in systems theory, AREs are also fascinating from a (pure) linear algebraic point of view, especially due to their close relations to (structured) eigenvalue problems and indefinite inner product spaces.

This minisymposium aims to bring together young researchers who have done recent work on the numerical solution of algebraic Riccati equations. Current research in the field of AREs mainly focuses on two areas, namely generalizations, and numerical treatment especially in the large-scale case. The talks within this minisymposium cover both of these research directions.

Regarding generalizations, two different nonsymmetric versions of the Riccati equations appear both in differential games which try to generalize the control approach to multiple competing controllers, and in applied probability and queuing theory, as a tool to solve equations appearing in the so-called fluid queues.

Regarding the numerical treatment of large-scale equations, different approaches exist. Unlike many other large-scale problems, implementing directly Krylov subspace techniques is challenging, as the solutions needed in the optimal control design depend on a function of the stable invariant subspace which is not computed easily from the leading eigenpairs. On the other hand, dense algorithms such as Newton's method can be extended to large-scale problems with the help of low-rank approximation techniques.

Speakers

	YR4: Numerical methods for the solution of algebraic Riccati equations	
Tuesday, 23.08.2011		**Room:**
10:30 - 11:00	**Jens Saak** *Acceleration of Newton-based Methods for Solving Large Sparse Algebraic Riccati Equations*	p. 76
11:00 - 11:30	**Hermann Mena** *On the Numerical Solution of Large Scale Differential Riccati Equations*	p. 76
11:30 - 12:00	**Tobias Breiten** *Solving Large-Scale Riccati Equations Arising in Stochastic Control*	p. 77
12:00 - 12:30	**Marc Jungers** *Feedback Stackelberg Strategy for Discrete-Time Descriptor Games*	p. 77

- end of session -

Jens Saak
MPI Magdebrug, Germany

Acceleration of Newton-based Methods for Solving Large Sparse Algebraic Riccati Equations

Tuesday, 23.08.2011, 10:30 - 11:00, Room to be filled in later by organizers

The low rank Cholesky factor Newton ADI (LRCF-NM) iteration is a valuable tool for solving large scale continuous time algebraic Riccati equations (AREs),

$$\mathcal{R}(X) := C^T C + A^T X + XA - XBB^T X = 0$$

where the real coefficient matrix A is sparse, its dimension n is *large* and B and C are thin or flat rectangular matrices, respectively. The solution X is sought after in factored form $X = ZZ^H$ for a possibly complex rectangular $n \times nz$ factor Z and $nz \ll n$. Although it is fairly efficient due to the low rank structure there are multiple parts in the algorithm that can be accelerated. In this contribution we will discuss several aspects like fast evaluation of the corresponding stopping criteria (e.g., $\|\mathcal{R}(ZZ^T)\|_2 < \varepsilon \|C^T C\|_2$ for a given tolerance ε) and acceleration of convergence by projection based optimization techniques for the low rank factors. Some numerical experiments prove that facilitating these we can drastically speed up the computation.

This contribution is joint work with Peter Benner (MPI Magdeburg, Germany).

Hermann Mena
Escuela Politécnica Nacional, Quito, Ecuador

On the Numerical Solution of Large Scale Differential Riccati Equations

Tuesday, 23.08.2011, 11:00 - 11:30, Room to be filled in later by organizers

The numerical analysis of linear quadratic regulator/gaussian design problems for parabolic partial differential equations requires solving large scale Riccati equations. In the finite time horizon case, the differential Riccati equation (DRE) arises. Typically, the coefficient matrices of the resulting DRE have a given structure (e.g. sparse, symmetric or low rank). Methods based on a matrix-valued implementation of the usual ODE methods exploit efficiently this structure. Here, we discuss several variants of the available methods, which allow to have a fast computation. In particular, we discussed the so-called W-methods (Rosenbrock type methods, in which the Jacobian matrix is retained for several steps), different ways for solving the resulting algebraic Riccati equation, and some parallel computing techniques for DREs. The performance of each of these methods is tested in numerical experiments.

This is joint work with Peter Benner (MPI Magdeburg, Germany).

Tobias Breiten
Max Planck Institute for Dynamics of Complex Technical Systems, Magdeburg

Solving Large-Scale Riccati Equations Arising in Stochastic Control

Tuesday, 23.08.2011, 11:30 - 12:00, Room to be filled in later by organizers

In this talk, we will discuss efficient solution techniques for large-scale quadratic matrix equations of the form

$$A^*X + XA + \sum_{j=1}^{m} A_j^* X A_j - XBB^*X + C^*C = 0.$$

These generalized Riccati equations have been shown to play an important role in stochastic control, see [T. Damm, D. Hinrichsen, Newton's method for a rational matrix equation occuring in stochastic control, *Linear Algebra Appl.*, Vol. 332-334:81-109, 2001], and can be iteratively solved by a Newton-type method which leads to certain generalized Lyapunov equations. We will propose a Krylov-subspace based approach which extends the successful K-PIK algorithm, see [V. Simoncini, A new iterative method for solving large-scale Lyapunov matrix equations, *SIAM J. Sci. Comput.*, Vol. 29:1268–1288, 2006], and additionally yields a low-rank representation of the solution of these Lyapunov equations. Since similar structures also appear in the context of bilinear control systems, we will additionally analyze their use with respect to control and model order reduction of these systems.
This contribution is joint work with Peter Benner (MPI Magdeburg,Germany).

Marc Jungers
CRAN UMR 7039 CNRS - Nancy Université ENSEM, France.

Feedback Stackelberg Strategy for Discrete-Time Descriptor Games

Tuesday, 23.08.2011, 12:00 - 12:30, Room to be filled in later by organizers

The *Stackelberg* strategies are suitable for two-person dynamic games, where there exists a hierarchy between the players, respectively called the *leader* and the *follower*. When the closed-loop information structure is considered, obtaining the Stackelberg strategies is a difficult issue, due to their time-inconsistency. Nevertheless, when the available information about the trajectory is memoryless, that is restricted to the current state, the Stackelberg strategies, thus called feedback, become strongly time consistent. This property allows to apply the Bellman's principle to the game. In this contribution we will provide a solution via a step by step backward in time numerical algorithm for discrete-time linear quadratic games. This original method is based on a matrix block formulation and the symmetry properties of an Hamiltonian matrix to avoid the canonical singular matrix decomposition. For an infinite time horizon, we will show that an implicit formulation of a *Algebraic Riccati type Equation* is obtained. Moreover an extension to descriptor games will be provided by using the same approach. Numerical examples illustrate the efficiency of the proposed method.

YR5

Bruno Iannazzo and Miklos Palfia
Dipartimento di Matematica e Informatica, Universita di Perugia, Italy
University of Technology and Economics, Budapest, Hungary

Matrix Means: Theory and Computation

Tuesday, 23.08.2011, 10:30 - 12:30

Despite the trivial generalization of the arithmetic mean to matrices, the generalization of the geometric mean of two positive numbers to positive definite matrices is far from being trivial. Imposing some expected properties, one gets a unique definition of geometric mean of two positive definite matrices A and B as

$$A\sharp B := A(A^{-1}B)^{1/2}.$$

Generalizing this approach to more than two matrices has been possible relying on a Riemannian manifold structure on the positive definite matrices and has not yet led to a unique definition of geometric mean of many matrices.
These difficulties together with the beautiful mathematics needed for studying matrix means, made it an active topic of interest in linear algebra [R. Bhatia. Positive definite matrices. Princeton Series in Applied Mathematics. Princeton University Press, Princeton, NJ, 2007].
On the other hand, averaging matrices is a problem arising when one has to represent, through a single matrix, the results of several experiments made up by a set of many matrices. This problem appears in applications to elasticity, radar, medical imaging, image processing, to cite just some [M. Moakher, On the averaging of symmetric positive-definite tensors, J. Elasticity, 2006], [F. Barbaresco, Foundation of Radar Doppler Signal Processing based on Advanced Differential Geometry of Symmetric Spaces: Doppler Matrix CFAR & Radar Application, 2009], [P. T. Fletcher and S. Joshi, Riemannian geometry for the statistical analysis of diffusion tensor data, Signal Processing, 2007], [Y. Rathi, O. Michailovich, and A. Tannenbaum, Segmenting images on the Tensor Manifold, 2007].
The purpose of the proposed minisymposium is to join the two souls of the research in matrix means: theory and computation, pure and applied linear algebra. This would be fruitful on one hand, to give to theoretical researchers new problems arising in applications, on the other hand, to provide strong mathematical foundation and effective numerical procedures in order to increase the quality of the applications.

Speakers

	YR5: Matrix Means: Theory and Computation	
Wednesday, 24.08.2011		**Room:**
10:30 - 10:50	**Ben Jeuris**	
	The matrix geometric mean and manifold optimization	p. 80
10:50 - 11:10	**Miklós Pálfia**	
	Affine means on differentiable manifolds	p. 80
11:10 - 11:30	**Hosoo Lee**	
	Higher genius Gauss and Borchardt means on Nonpositively curved normal cones	p. 81
11:30 - 11:50	**Quentin Rentmeesters**	
	Comparison of gradient and Newton methods for Karcher mean computation of rotation matrices and symmetric positive definite matrices	p. 81
11:50 - 12:10	**Federico Poloni**	
	Constructing new matrix geometric means (or the impossibility thereof)	p. 82
12:10 - 12:30	**Sejong Kim**	
	Weighted Means on Smooth Manifold with Spray	p. 82

- end of session -

Ben Jeuris
Katholieke Universiteit Leuven, Belgium,
ETH-Zürich, Switzerland

The matrix geometric mean and manifold optimization

Wednesday, 24.08.2011, 10:30 - 10:50, Room to be filled in later by organizers

In this talk we will discuss numerical techniques for computing a matrix geometric mean. The generalization of the scalar geometric mean to matrices has proven to be non-trivial and as a consequence lacks a unique definition. We will first analyse the properties of some existing algorithms for calculating geometric matrix means. These algorithms were constructed from geometric and axiomatic points of view to satisfy some necessary and desirable properties of the averaging of symmetric positive definite matrices. It is shown that these properties do not specify a unique definition for the geometric matrix mean, resulting in different valid algorithms of varying performance. Afterwards we compare these results to our newly implemented version of the Karcher mean. This mean is constructed from a center-of-mass-principle by optimizing on the manifold of positive definite matrices, using the intrinsic Riemannian metric.

This contribution is joint work with Raf Vandebril (K.U.Leuven, Belgium) and Bart Vandereycken (ETH-Zürich, Switzerland).

Miklós Pálfia
Department of Automation and Applied Informatics, Budapest University of Technology and Economics

Affine means on differentiable manifolds

Wednesday, 24.08.2011, 10:50 - 11:10, Room to be filled in later by local organizers

We give a sufficient definition of a 2-variable weighted matrix mean corresponding to every symmetric matrix mean. The definition is based on a geometrical picture. The geometrical approach is closely related to some metric structures corresponding to the arithmetic, geometric and harmonic means. These means are geometric midpoints on the differentiable manifold of positive definite matrices equipped with an affine connection. In each of these three cases the connections are metric, they are the Levi-Civita connections of Riemannian metrics.

Motivated by the above geometrical picture we investigate affine matrix means, which are defined to be symmetric matrix means that are midpoint operations of an affine connection on the differentiable manifold of positive definite matrices. Affine means are important since the extension of 2-variable matrix means are closely related to certain metric structures. For instance the construction of the Ando-Li-Mathias and Bini-Meini-Poloni geometric mean and the Riemannian mean of Moakher explicitly builds on the Riemannian structure corresponding to the geometric mean.

We will classify all possible affine matrix means, by finding the possible affine connections corresponding to them. To settle down the metrizability problem we will find out which of these connections are metric. In the meantime we study some further properties of these affine connections.

Hosoo Lee
Kyungpook National University

Higher genius Gauss and Borchardt means on Nonpositively curved normal cones

Wednesday, 24.08.2011, 11:10 - 11:30, Room to be filled in later by organizers

In this talk we propose a definition for an arithmetic-geometric mean of n-variables on nonpositively curved convex normal cones via the standard mean iteration involving arithmetic mean and geometric midpoint existing on the cone. We show that the arithmetic-geometric mean satisfies multidimensional versions of all properties that one would expect for the two-variable Gauss mean of positive reals. A perturbation and error analysis of the convergence are presented via the Thompson metric. It is further shown that the convergence is uniform on each closed ball in the normal cone.

This contribution is joint work with Yondo Lim (Kyungpook National University, Korea).

Quentin Rentmeesters
Department of Mathematical Engineering
Université catholique de Louvain

Comparison of gradient and Newton methods for Karcher mean computation of rotation matrices and symmetric positive definite matrices

Wednesday, 24.08.2011, 11:30 - 11:50, Room to be filled in later by organizers

This talk concerns the computation, by means of gradient and Newton methods, of the Karcher mean, see [Karcher, Riemannian center of mass and mollifier smoothing, Communications on pure and applied mathematics, 1977], of a finite collection of points, both on the manifold of 3×3 rotation matrices $SO(3)$ endowed with its usual bi-invariant metric and on the manifold of 3×3 symmetric positive definite matrices P_3^+ endowed with its usual affine invariant metric. An explicit expression for the Hessian of the Riemannian squared distance function of these manifolds is given. From this, a condition on the step size of a constant step gradient method that depends on the data distribution is derived. These explicit expressions make a more efficient implementation of the Newton method presented in [Ferreira, Xavier, Costeira, Barroso, Newton method for Riemannian centroid computation in naturally reductive homogeneous spaces, ICASSP, 2006] possible and it is shown that, in terms of computational time, the Newton method outperforms the gradient method in some cases. The extension of the proposed methods to $SO(n)$ and P_n^+ for larger n and to the Grassmann manifold is also discussed.

This contribution is joint work with P.-A. Absil (Université catholique de Louvain).

Federico Poloni
Scuola Normale Superiore, Pisa, and Technische Universität Berlin

Constructing new matrix geometric means (or the impossibility thereof)

Wednesday, 24.08.2011, 11:50 - 12:10, Room to be filled in later by organizers

We present a framework that formalizes the construction of matrix geometric means by composition of means of fewer variables and limit processes. It includes the constructions described in [Ando, Li, Mathias, Geometric means, 2004], [Pálfia, The Riemann barycenter computation and means of several matrices, 2009], [Nakamura, Geometric means of positive operators, 2009], [Bini, Meini, Poloni, An effective matrix geometric mean satisfying the Ando–Li–Mathias properties, 2010].
We define a *quasi-mean* as a function of several matrices that respects all the Ando–Li–Mathias properties, except from the fact that it need not be invariant with respect to changing the order of its arguments. We study the *invariance group* of a quasi-mean, i.e., the subgroup of the permutations of its arguments which leave it unchanged.
We generalize in this framework the arguments used in the cited papers to prove the invariance properties of the means considered therein. Using group-theoretical techniques, we prove that said arguments cannot yield a mean of k matrices that satisfies all Ando–Li–Mathias properties *and* can be computed using less than $O(k!)$ means of two matrices.
As a byproduct, we find a mean of 4 matrices that is substantially cheaper to compute than the existing ones.

Sejong Kim
Louisiana State University

Weighted Means on Smooth Manifold with Spray

Wednesday, 24.08.2011, 12:10 - 12:30

On a smooth manifold we introduce a notion of spray and Loos symmetric space. We see that the open convex cone of positive definite matrices is a Loos symmetric space equipped with spray. Moreover, using the result that any two points in a normal neighborhood are joined by a unique geodesic, we define weighted means using the exponential map and find their properties.

This contribution is joint work with Jimmie Lawson (Louisiana State University, Baton Rouge, U.S.A.).

YR6

Jens Saak and Alfredo Remon
Max Planck Institute Magdeburg, Germany
Universidas Jaume I, Spain

Parallel Computing in Numerical Linear Algebra

Wednesday, 24.08.2011, 10:30 - 12:30

The solution of many scientific applications require the computation of large linear algebra operations. Thus, Parallel Computing has always been closely related to numerical linear algebra. On the other hand new algorithms in numerical linear algebra often needed to answer the question, how they could be used on parallel machines to tackle also very large problems. To solve this question, mathematicians and computer engineers should work jointly developing new algorithms and software. Over decades, due to their high cost, parallel computers have only been used to make extraordinarily large problems solvable which have been way to large to be solved on a desktop machine. During the recent years two major developments have caused a new way of thinking. On the one hand CPU manufacturers have circumvented the miniaturization and clock frequency limits they were facing by placing several processing units onto a single chip. The further increase of computing power now is due to exploitation of this multi-core-technology. On the other hand general purpose graphics processors (GPGPUs) have become so tremendously powerful, that they are nowadays competitive and in many cases even superior to CPUs in terms of computing power. Their SIMD (Single Instruction Multiple Data) architecture make them suitable for vector operations and especially eligible for linear algebra applications. In this case one can even speak of many-core-technology due to the very large number of processing units per device (in the order of hundreds). Both these developments make it necessary to rethink numerical linear algebra codes to exploit the features of these new processing units in the algorithms and especially in the codes to use recent computing hardware in the desktop section efficiently. We have chosen a handful of researchers from both disciplines (mathematicians and computing engineers) that have driven multi-core- and GPU computing forward during the recent years and participated in the first steps towards closing the performance gap that has been opened by these technologies.

Speakers

	YR6: Parallel Computing in Numerical Linear Algebra	
Wednesday, 24.08.2011		**Room:**
10:30 - 11:00	**Martin Köhler**	
	Solving large scale matrix equations on multicore-CPUs	p. 85
11:00 - 11:30	**Alberto F. Martín**	
	Exploiting Thread-Level Parallelism in the Multilevel ILU Preconditioning of Large Sparse Linear Systems	p. 85
11:30 - 12:00	**Dominik Göddeke**	
	Mixed-Precision GPU-Multigrid Solvers with Strong Smoothers	p. 86
12:00 - 12:30	**Matthias Petschow**	
	The symmetric tridiagonal eigenproblem on massively-parallel supercomputers	p. 86

- end of session -

Martin Köhler
Max Planck Institute for Dynamics of Complex Technical Systems, Magdeburg

Solving large scale matrix equations on multicore-CPUs

Wednesday, 24.08.2011, 10:30 - 11:00, Room to be filled in later by organizers

Many applications in control theory depend on the solution of Lyapunov, Sylvester or Riccati equations. The efficient solution of these equations is a key ingredient for many algorithms in balancing based model order reduction, $\mathcal{H}_2$ model order reduction, and optimal control of ODEs/PDEs. The case where the matrices in these equations are relatively small is covered by many well known algorithms like Bartel-Stewart method, sign function method or Schur vector methods. They can easily be accelerated by using level-3 BLAS operations. More interesting is the solution of so called "large scale" equations with sparse coefficient matrices. There, new technologies like the low rank ADI method, low rank Newton-ADI method for the Riccati equation or special sparse-dense Sylvester solvers are necessary. We will give an overview on how these new algorithms can be accelerated on modern computers by exploiting their multicore capabilities using OpenMP and PThreads. In order to show a memory saving technique, we will discuss the solution of a sequence of linear systems $(A+p_iI)x=b,\ i=1,\dots,r$ in a little more detail and show how the parallelization can be done.

This contribution is joint work with Peter Benner and Jens Saak (both MPI Magdeburg, Germany).

Alberto F. Martín
Centre Internacional de Mètodes Numèrics a l'Enginyeria, Barcelona, Spain

Exploiting Thread-Level Parallelism in the Multilevel ILU Preconditioning of Large Sparse Linear Systems

Wednesday, 24.08.2011, 11:00 - 11:30, Room to be filled in later by organizers

The efficient solution of large and sparse linear systems is one of the problems in modern linear algebra which arises most frequently in scientific and engineering applications. The solution of these systems in a moderate time requires: (1) algorithms with a high degree of algorithmic efficiency and scalability and (2) parallel computing techniques which efficiently expose/exploit the concurrence available in these methods on parallel computers with enough computational resources. In order to address issue (1) the algebraic multilevel solvers included in ILUPACK are considered. This package implements multilevel preconditioners constructed from *inverse-based* ILUs combined with Krylov iteration methods. Its main use consists of application problems such as linear systems arising from PDEs, and it has been successfully applied to several large scale application problems as, e.g., the Anderson model of localization. The talk will be focused on issue (2) and, in particular, on the design of parallel algorithms able to efficiently expose and exploit on shared-memory multiprocessors the task-level parallelism available in the solvers of the ILUPACK library, while still preserving the semantics of the serial preconditioning approach.
This contribution is joint work with José Aliaga, E.S. Quintana-Ortí (Universitat Jaume I, Castellón) and Matthias Bollhöfer (TU Braunschweig, Germany).

Dominik Göddeke
Institut für Angewandte Mathematik (LS3), TU Dortmund, Germany

Mixed-Precision GPU-Multigrid Solvers with Strong Smoothers

Wednesday, 24.08.2011, 11:30 - 12:00, Room to be filled in later by organizers

We present efficient parallelisation strategies for geometric multigrid solvers on GPUs. Such solvers are a fundamental building block in the solution of PDE problems using discretisation techniques like finite elements, finite differences and finite volumes. Generalised tensor product meshes, unstructured meshes and their block-structured combination are considered. Special focus is placed on numerically strong smoothers, which are challenging to parallelise due to their inherently sequential, recursive character. However, many practical problems require strong smoothers, in particular in the presence of anisotropies in the differential operator, the underlying mesh, or both. We address the inherent trade-off between numerical and hardware performance, i.e., between global coupling and degree of parallelism. To further improve performance, a mixed precision strategy is applied. By carefully balancing these contradictory requirements, we achieve more than an order of magnitude speedup over highly optimised CPU code for a number of challenging test problems, without affecting the numerical performance of our solver.

This contribution is joint work with Robert Strzodka (Max Planck Institut Informatik, Saarbrücken, Germany).

Matthias Petschow
RWTH Aachen, Germany

The symmetric tridiagonal eigenproblem on massively-parallel supercomputers

Wednesday, 24.08.2011, 12:00 - 12:30, Room to be filled in later by organizers

The symmetric tridiagonal eigenproblem (STEP) is of special importance as it lies at the heart of many methods for computing eigenvalues and eigenvectors of dense Hermitian or symmetric matrices. In the last three decades very efficient and reliable methods for the STEP have been developed—namely the Divide-and-Conquer algorithm and the method of Multiple Relatively Robust Representations (MRRR). In large distributed-memory parallel environments the latter is found especially suitable, both because of its low complexity and scalability. In order to take advantage of today's hybrid architectures we have developed a version of the MRRR algorithm designed for both message-passing and shared-memory for communication. Parallelism is achieved by dividing the work statically among all—possibly multi-threaded—processes, while the work associated to each process is divided dynamically into tasks which can then be executed by many threads. It is therefore possible to use shared-memory for inter-node communication and message-passing for intra-node communication—a programming model gaining popularity in recent years. We will discuss benefits of this hybrid approach for the STEP. We will further show how the approach impacts the solution of dense Hermitian or symmetric standard and generalized eigenproblems.

This contribution is joint work with Paolo Bientinesi (RWTH Aachen, Germany).

YR7

Rob M.P. Goverde and Sergeĭ Sergeev
Delft University of Technology (the Netherlands), INRIA and CMAP Ecole Polytechnique (France)

Max-plus linearity and its applications in computer science and scheduling

Tuesday, 23.08.2011, and Wednesday, 24.08.2011, 10:30 - 12:30

Max-plus linear algebra can be regarded as a kind of linear algebra over real numbers where the usual addition is replaced by $a \oplus b := \max(a, b)$ and the usual multiplication is replaced by addition $a \otimes b := a + b$. The new arithmetics is then extended to matrices and vectors in the usual way.

The development of this area is motivated on one hand by intimate connections to nonnegative linear algebra which allow to build max-algebraic analogues of the classical notions and constructions like matrix rank,linear independence and convexity. One can either look at the classical notions and apply the logarithmic limit $\max(a, b) = \lim_{h\to 0^+} h \log(e^{a/h} + e^{b/h})$, or develop original proof methodology of algebraic or combinatorial nature.

On the one hand, the logarithmic limit above provides useful connection with classical linear algebra which can be used in both directions. In particular, methods of max-plus algebra have been used to introduce a general scaling technique for the eigenvalues of matrix polynomials (**Meisam Sharify** and Stéphane Gaubert). In a different area, the logarithmic passage was used to give an elegant proof of Berger-Wang formula for the joint spectral radius in max-plus algebra (**Aljoša Peperko**). Even if the direct application of the logarithmic limit is not so convenient, it allows to introduce max-algebraic analogues of classical notions of linear algebra and semigroup theory. See the talks of **Buket Benek Gursoy** and **Marianne Johnson**.

On the algebraic side, max-plus algebra has close connections to the theory of fuzzy sets and to the fuzzy algebras, where the minimization or the triangular norm (t-norm, drastic norm, product norm) plays the role of multiplication (talks of **Imran Rashid** and **Hana Tomaškova**). On the combinatorial side, max-plus algebra extensively uses methods and terminology coming from connectivity theory of graphs and, more recently, hypergraphs (talk of **Xavier Allamigeon**).

On the other hand, there are practical applications of the max-plus algebra in scheduling, see the book by Baccelli et al. "Synchronization and linearity",as well as design of asynchronous circuits and multiprocessor systems. The max-plus linear recursion $x(k + 1) = A \otimes x(k) \oplus d(k)$ where $d(k) = d(0) + kT$ models the delay propagation in a railway network. Here $x(k)$ is the vector of train departure times, $d(k)$ is the regular schedule (typically $T = 60$ minutes), and $\otimes$ denotes the max-plus matrix-vector product. See PhD Thesis and talk of **Rob Goverde**,and also the monograph by Heidergott et al. "Max-plus at work". More complicated models can arise from other scheduling problems using the formalism of Petri nets, see works of J.-P. Quadrat and **Nadir Farhi**. Random perturbations in the network are modelled by means of stochastic max-plus models, see the talk of **James Hook**.

It was recently understood that max-plus convex polytopes, represented typically as solution set of systems of max-plus affine inequalities, can be applied in static analysis of programs, handling disjunctive constraints of the type $\max(a, b) \geq c$ (talk of **Xavier Allamigeon**).

Speakers

	YR7.1: Max-plus linearity and its applications in computer science and scheduling (PART I)	
Tuesday, 23.08.2011		**Room:**
10:30 - 11:00	**Rob M.P. Goverde**	
	Sparse matrix computations in max-plus algebra and its application to large-scale railway timetable analysis	p. 90
11:00 - 11:30	**Xavier Allamigeon**	
	Algorithmics of tropical polyhedra, and application to software verification	p. 90
11:30 - 12:00	**Meisam Sharify**	
	Scaling of matrix polynomials by means of tropical algebra	p. 91
12:00 - 12:30	**Aljosa Peperko**	
	Spectral radius in tropical algebra	p. 91
	YR7.2: Max-plus linearity and its applications in computer science and scheduling (PART II)	
Wednesday, 24.08.2011		**Room:**
10:30 - 10:50	**Buket Benek Gursoy**	
	$P^1_{\max}$ *and* $S_{\max}$ *properties and asymptotic stability in the tropical linear algebra*	p. 92
10:50 - 11:10	**Marianne Johnson**	
	Green's $\mathcal{J}$*-order and the rank of max-plus matrices*	p. 92

- to be continued -

YR7.2: Max-plus linearity and its applications in computer science and scheduling (PART II - continuation)

Wednesday, 24.08.2011		Room:
11:10 - 11:30	**Nadir Farhi**	
	A network calculus approach for the calculus of performance bounds in SpaceWire-like routers	p. 93
11:30 - 11:50	**Imran Rashid**	
	Eigenspace structure of max-t fuzzy matrices	p. 93
11:50 - 12:10	**Hana Tomášková**	
	Inverse eigenproblem in max-min algebra	p. 94
12:10 - 12:30	**James Hook**	
	Products of i.i.d. componentwise exponential max-plus matrices	p. 94

- end of session -

Rob M.P. Goverde
Delft University of Technology, The Netherlands

Sparse matrix computations in max-plus algebra and its application to large-scale railway timetable analysis

Tuesday, 23.08.2011, 10:30 - 11:00, Room to be filled in later by organizers

Max-plus linear systems are a special class of discrete event dynamic systems (DEDS) where the system dynamics are described by linear equations in max-plus algebra of the general form $x(k) = \bigoplus_{l=0}^{p} A_l \otimes x(k-l)$, $k \geq 1$, with square matrices $A_l \in \mathbb{R}_{\max}^{n \times n}$, $l = 0, \ldots, p$, and given initial conditions. Such linear systems correspond to the dynamics of timed event graphs (TEG). In practical applications the state matrices $A_0, \ldots, A_p$ are very large but sparse. An efficient representation of these sparse systems uses $O(m)$ space instead of $O((p+1)n^2)$ space for the matrix notation, where m is the number of nonzeros (finite entries) in the $p+1$ matrices A_l. This paper gives an efficient sparse matrix-vector multiplication algorithm running in $O(m)$ time that uses this sparse matrix representation directly, as opposed to the $O((p+1)n^3)$ time algorithm for straightforward matrix-vector multiplication. An analogue $O(m)$ sparse matrix representation can be defined for stochastic max-plus linear systems $x(k) = \bigoplus_{l=0}^{p} A_l(k) \otimes x(k-l)$, $k \geq 1$, with the nonzero matrix entries following probability distributions with given parameters, enabling effective Monte Carlo simulations. These sparse computations enable computations of large-scale max-plus linear systems, which is demonstrated by a real-world application of the national railway system in the Netherlands.

Xavier Allamigeon
INRIA and CMAP, Ecole Polytechnique, France

Algorithmics of tropical polyhedra, and application to software verification

Tuesday, 23.08.2011, 11:00 - 11:30, Room to be filled in later by organizers

Tropical polyhedra refer to the analogues of convex polyhedra in tropical algebra. We develop a tropical analogue of the classical double description method, allowing one to compute an internal representation (in terms of vertices) of a polyhedron defined externally (by inequalities). The heart of the method is a combinatorial characterization of the extreme points of a tropical polyhedron in terms of a system of constraints which define it. We show that a point of a tropical polyhedron is extreme if and only if a directed hypergraph, which we construct from the subdifferentials of the active constraints at this point, admits a unique terminal strongly connected component. We provide theoretical worst case complexity bounds and report extensive experimental tests performed using an OCaml implementation called TPLib, showing that this method outperforms the previous ones.
We also discuss some applications to software verification, and show that tropical polyhedra are able to express disjunctive program invariants allowing to automatically ensure the absence of errors in software.

This contribution is joint work with Stéphane Gaubert (INRIA and CMAP, Ecole Polytechnique, France), Eric Goubault (CEA, LIST MeASI, France), and Ricardo D. Katz (CONICET, Argentina).

Meisam Sharify
INRIA and CMAP, École Polytechnique

Scaling of matrix polynomials by means of tropical algebra

Tuesday, 23.08.2011, 11:30 - 12:00, Room to be filled in later by organizers

We have developed a scaling method based on tropical algebra, to increase the accuracy of the computation of the eigenvalues of a matrix polynomial problem. This scaling is based on computing tropical roots, which can be done in linear time. For a formal polynomial, we have proved that the tropical roots can provide an a priori estimation of the modulus of the formal roots. In the general case, when the dimension is greater than one, we established a theorem corresponding to the smallest and the largest tropical roots, showing that, these roots can provide an a priori estimation of the modulus of the relevant groups of eigenvalues. We show, by experiments, that this scaling improves the accuracy (measured by normwise backward error) of the computations, particularly in situations in which the data have various orders of magnitude.

This contribution is joint work with Stéphane Gaubert (INRIA and CMAP, École Polytechnique).

Aljosa Peperko
University of Ljubljana, Slovenia

Spectral radius in tropical algebra

Tuesday, 23.08.2011, 12:00 - 12:30, Room to be filled in later by organizers

New results about the spectral radius in max algebra and related areas will be presented. In particular, the results on max type operators in infinite dimensions will be considered. Some related applications will be included in the talk.

Buket Benek Gursoy
Hamilton Institute, National University of Ireland, Maynooth

$P^1_{\max}$ and $S_{\max}$ properties and asymptotic stability in the tropical linear algebra

Wednesday, 24.08.2011, 10:30 - 10:50, Room to be filled in later by organizers

In this study, we consider $P^1_{\max}$ and $S_{\max}$ properties of matrices in the max algebra and derive several results characterising these properties that echo corresponding results for P-matrices in the conventional algebra. Further, we obtain results elucidating the relationship between the $P^1_{\max}$-property, the $S_{\max}$-property and the stability of delayed difference equations.
Next, we consider a finite set of $n \times n$ nonnegative matrices given by $\Psi := \{A_1, A_2, ..., A_p : p > 0\}$. Motivated by [Y. Song et al., On some properties of P-matrix sets], we define $P^1_{\max}$-matrix sets and the row-$P^1_{\max}$-property and the $S_{\max}$-property of Ψ. Further, we describe a number of equivalent characterisations of $P^1_{\max}$-matrix sets. In particular, we show the relationship of these sets with the stability of the max convex hull of Ψ and of discrete inclusions with delay of the following type:

$$x_i(k+1) \in \bigoplus_{j=1}^{n} a^w_{ij} x_j(k - \tau_{ij}), i = 1, 2, ..., n, w \in \{1, 2, ..., p\} \tag{3.1}$$

where $A_w \in \Psi$ and $\tau_{ij} \geq 0$ for all $1 \leq i, j \leq n$.
This contribution is joint work with Oliver Mason (Hamilton Institute, National University of Ireland, Maynooth).

Marianne Johnson
University of Manchester, UK

Green's $\mathcal{J}$-order and the rank of max-plus matrices

Wednesday, 24.08.2011, 10:50 - 11:10, Room to be filled in later by organizers

We give a characterisation of *Green's $\mathcal{J}$-order* on the multiplicative semigroup of all $n \times n$ matrices with entries in the max-plus semiring. Green's $\mathcal{J}$-order (and the corresponding $\mathcal{J}$-relation) can be defined upon any semigroup and encapsulates the two-sided ideal structure. For elements A, B of our semigroup we say that $A \leq_{\mathcal{J}} B$ if the two-sided ideal generated by A is contained in the two-sided ideal generated by B. If A and B generate the same two-sided ideal we say that A is $\mathcal{J}$-related to B and thus it is easy to see that this is an equivalence relation.
In the case of matrices with entries in a field, the $\mathcal{J}$-relation corresponds exactly to the idea of rank, that is, two matrices are $\mathcal{J}$-related if and only if they have the same rank. For max-plus matrices many of the non-equivalent notions of rank turn out to be $\mathcal{J}$-class invariants, perhaps suggesting that the max-plus analogue of the rank of a matrix should not be a single natural number, but rather a $\mathcal{J}$-class.
This contribution is joint work with Mark Kambites (University of Manchester, UK).

Nadir Farhi
UPE, IFSTTAR, GRETTIA, Le Descartes II, Noisy-Le-Grand, France.

A network calculus approach for the calculus of performance bounds in SpaceWire-like routers

Wednesday, 24.08.2011, 11:10 - 11:30, Room to be filled in later by organizers

We propose an approach for the calculus of performance bounds (on the service, the delays and the backlogs) for data packets passing through a spacewire-like routing switch, where the packets are allowed to have different lengths. The approach is based in network calculus theory, where constraints on data arrivals and service are expressed in minimum and maximum curves. We define a new kind of curves that we call packet curves, in order to take into account the variance of packet lengths. Using the packet curve concept, we give a network calculus-based model for the calculus of performance bounds on a spacewire-like switch. Several packet flows arriving to the input ports of the switch are routed under packet-based FIFO policy to the corresponding destination output ports, where they are served under the round-robin service discipline. The extension of the model to feed-forward networks by the connection of several routers gives a model of the wormhole routing discipline.

This contribution is joint work with Anne Bouillard (INRIA - TREC, Paris, France) and Bruno Gaujal (INRIA and LIG, Grenoble, France).

Imran Rashid
University of Hradec Kralove

Eigenspace structure of max-t fuzzy matrices

Wednesday, 24.08.2011, 11:30 - 11:50, Room to be filled in later by organizers

The structure of the monotone eigenspace (the set of all monotone eigenvectors) of a given fuzzy matrix is considered. Necessary and sufficient conditions are presented under which the monotone eigenspace of a given matrix is non-empty and, in the positive case, the structure of the monotone eigenspace is described. Permutations on the rows/columns of the matrix are then used to described the complete structure of the eigenspace. Fuzzy matrices are considered in max-t algebra for triangular norm t, equal to product, drastic and Łukasiewicz norms. The work is a continuation of the previous work of one of the authors. The monotone eigenspace of a max-min fuzzy matrix has been described as a union of intervals in [Gavalec M., Monotone eigenspace structure in max-min algebra, Lin. Algebra Appl., 345 (2002), 149–167].

The support of Czech Science Foundation # 402/09/0405 is kindly acknowledged.

This contribution is a joint work with Richard Cimler (UHK Hradec Kralove, Czech Republic).

Hana Tomášková
Univerzity of Hradec Kralové, Czech Republic

Inverse eigenproblem in max-min algebra

Wednesday, 24.08.2011, 11:50 - 12:10, Room to be filled in later by organizers

In the inverse eigenproblem the set of all matrices A fulfilling the equation $Ax = x$ for a given strictly increasing eigenvector x is investigated. It is assumed that matrices belong to given matrix interval $\mathbf{A} = [\underline{A}; \overline{A}]$. The inverse eigenproblem is investigated in max-min algebra. By max-min algebra we understand a triple $(B, \oplus, \otimes)$, where B is a linearly ordered set, and $\oplus = \max$, $\otimes = \min$ are binary operations on B. The notation $B(m,n)$ ($B(n)$) denotes the set of all matrices (vectors) of given dimension over B. Operations $\oplus$, $\otimes$ are extended to matrices and vectors in a formal way. The inverse interval eigenproblem is closely related to the direct eigenproblem with interval inputs values which has been studied in [Gavalec, Plavka, Monotone interval eigenproblem in max-min algebra. Kybernetika 46 (2010), 387-396].

The support of Czech Science Foundation # 402/09/0405 is kindly acknowledged.

This contribution is joint work with Zuzana Němcová (Univerzity Hradec Králové, Czech Republic).

James Hook
University of Manchester

Products of i.i.d. componentwise exponential max-plus matrices

Wednesday, 24.08.2011, 12:10 - 12:30, Room to be filled in later by organizers

Products of i.i.d. max-plus matrices arise naturally in a variety of queueing type systems. For matrices whose non-zero components are i.i.d. exponentials we obtain a sandwich inequality relating the Lyapunov exponent of the max-plus system to the principal eigenvalue of an associated standard (i.e. not max-plus) matrix.

Chapter 4

Contributed Sessions

CS1: Numerical Methods for Linear Systems

CS1.1: Numerical Methods for Linear Systems (PART I)

Monday, 22.08.2011 — Chair: Miroslav Rozložník — **Room:**

15:30 - 15:50	**Matthias Bolten** *Aggregation-based multigrid for circulant and Toeplitz matrices*	p. 98
15:50 - 16:10	**Yvan Notay** *Multigrid methods from the numerical linear algebra viewpoint*	p. 98
16:10 - 16:30	**Achim Basermann** *Scalable Preconditioned Solvers for Internal and External Flow Computations on Many-Core Systems*	p. 99
16:30 - 16:50	**Martin Stoll** *All-at-once solution of time-dependent PDE-constrained optimization problems*	p. 99

CS1.2: Numerical Methods for Linear Systems (PART II)

Monday, 22.08.2011 — Chair: 1.2 — **Room:**

17:00 - 17:20	**Miroslav Rozložník** *Approximate inverse preconditioning and Gram-Schmidt orthogonalization*	p. 100
17:20 - 17:40	**Seiji Fujino** *A proposal of Multi-Restarts type of Look-Back GMRES(k) methods*	p. 100
17:40 - 18:00	**Daniel B. Szyld** *Short-term-recurrence method (and preconditioner) for nearly-Hermitian linear systems*	p. 101

- to be continued -

	CS1.2: Numerical Methods for Linear Systems (PART II - continuation)	
Monday, 22.08.2011	Chair: 1.2	**Room:**
18:00 - 18:20	**Yimin Wei**	
	Convergence of General Nonstationary Iterative Methods for Solving Singular Linear Equations	p. 101
18:20 - 18:40	**Jesse Barlow**	
	Block Gram–Schmidt Algorithms	p. 102

	CS1.3: Numerical Methods for Linear Systems (PART III)	
Tuesday, 23.08.2011	Chair: 1.3	**Room:**
15:30 - 15:50	**Zdeněk Strakoš**	
	On the continuous problem context of matrix computations in solving boundary value problems	p. 102
15:50 - 16:10	**Miroslav Tůma**	
	Mixed direct-inverse decompositions and applications	p. 103
16:10 - 16:30	**Jörg Liesen**	
	On the convergence of GMRES for a convection-diffusion model problem	p. 103
16:30 - 16:50	**Jens-Peter M. Zemke**	
	IDR: A new generation of Krylov subspace methods?	p. 104

- end of session -

Matthias Bolten
Bergische Universität Wuppertal

Aggregation-based multigrid for circulant and Toeplitz matrices

Monday, 22.08.2011, 15:30 - 15:50, Room to be filled in later by organizers

The convergence theory for multigrid methods for Toeplitz matrices and circulant matrices is based on the knowledge of the position and order zeros of the generating symbol of the respective operator and by using a cutting matrix K to keep the structure of the original system. As the system is analyzed using the variational theory, the coarse grid operator is defined as the Galerkin operator $A_C = P^H AP$. In the analysis, the classical smoothing property and the approximation property are translated to specific requirements that the generating symbols have to fulfill.
Besides the classical AMG approach algebraic multigrid methods based on aggregation and smoothed aggregation are widely used.
We analyzed aggregation and smoothed aggregation in the context of the convergence theory for Toeplitz and circulant matrices. As in the aggregation-based multigrid methods, for generating symbols with a single isolated zero at the origin aggregates are formed. The interpolation can then be improved by applying another operator. This improvement can be interpreted as the smoothing step in the original smoothed aggregation method. In the talk the various approaches and the analysis of the resulting operators in terms of their generating symbols will be presented.

Yvan Notay
Universite Libre de Bruxelles

Multigrid methods from the numerical linear algebra viewpoint

Monday, 22.08.2011, 15:50 - 16:10, Room to be filled in later by organizers

Multigrid methods are among the most efficient techniques to solve large sparse linear systems arising from the discretization of elliptic second order PDEs.
Historically, these methods have their foundations in the theory of PDEs and of their discretization, and the solution process requires information from the discretization.
However, *algebraic* variants exist that can work stand alone. These trace back to the eighties, but were for a long time mainly developed on a heuristic basis.
Now, these last years have seen the emergence of an algebraic convergence theory, and, with the recent developments, algebraic multigrid methods can be analyzed from a purely numerical linear algebra viewpoint. Moreover, these developments also allowed the effective improvement of the techniques, thanks to the integration of typical numerical linear algebra ingredients like Krylov subspace methods.
In the last instance, this led to a method of black-box type and whose convergence is guaranteed for any symmetric M-matrix with nonnegative row sum.
In this somehow non conventional talk, we shall review these results, stressing the points that are most interesting for a typical attendee of the meeting.
In particular, an excerpt of open linear algebra problems will be given, whose solution could help further developments in multigrid methods.

Achim Basermann
German Aerospace Center (DLR), Simulation and Software Technology, Porz-Wahnheide, Linder Höhe, Cologne, Germany

Scalable Preconditioned Solvers for Internal and External Flow Computations on Many-Core Systems

Monday, 22.08.2011, 16:10 - 16:30, Room

At the German Aerospace Center (DLR), the parallel simulation systems TAU and TRACE have been developed for the aerodynamic design of aircrafts or turbines for jet engines. Large-scale computing resources allow more detailed numerical investigations with bigger numerical configurations. Up to 50 million grid points in a single simulation are becoming a standard configuration in the industrial design. Both CFD solvers, TAU and TRACE, require the parallel solution of large, sparse real or complex systems of linear equations. For the parallel iterative solution of these equation systems, various block-local preconditioners are compared with global Distributed Schur Complement (DSC) preconditioning methods for real or complex matrix problems. Numerical, performance and scalability results of preconditioned FGMRes algorithms are presented for typical TAU and TRACE problems from external or internal flow simulations on many-core systems together with an analysis of the avantages of the complex problem formulation.

This contribution is joint work with Hans-Peter Kersken (DLR, Simulation and Software Technology, Cologne, Germany).

Martin Stoll
Computational Methods in Systems and Control Theory
Max Planck Institute for Dynamics of Complex Technical Systems

All-at-once solution of time-dependent PDE-constrained optimization problems

Monday, 22.08.2011, 16:30 - 16:50, Room to be filled in later by organizers

Time-dependent partial differential equations (PDEs) play an important role in applied mathematics and many other areas of science. One-shot methods try to compute the solution to these problems in a single iteration that solves for all time-steps at the same time. In this talk, we look at one-shot approaches for the optimal control of time-dependent PDEs such as the heat equation or the unsteady Stokes problem and focus on the fast solution of these problems. The use of Krylov subspace solvers together with an efficient preconditioner allows for minimal storage requirements. We solve only approximate time-evolutions for both forward and adjoint problem and compute accurate solutions of a given control problem only at convergence of the overall Krylov subspace iteration. We show that our approach can give competitive results for a variety of problems.

This contribution is joint work with Andy Wathen (Oxford University, UK).

Miroslav Rozložník
Institute of Computer Science, Czech Academy of Sciences, Prague, Czech Republic

Approximate inverse preconditioning and Gram-Schmidt orthogonalization

Monday, 22.08.2011, 17:00 - 17:20, Room to be filled in later by organizers

One of the most important and frequently used preconditioning techniques for solving symmetric positive definite systems is based on computing the approximate inverse factorizations. It is also a well-known fact that such factors can be computed column by the orthogonalization process applied to the unit basis vectors provided that we use a non-standard inner product induced by the positive definite system matrix A. In this contribution we consider the classical Gram-Schmidt algorithm (CGS), the modified Gram-Schmidt algorithm (MGS) and also yet another variant of sequential orthogonalization, which is motivated originally by the AINV preconditioner and which uses oblique projections. The orthogonality between computed vectors is crucial for the quality of the preconditioner constructed in the approximate inverse factorization. While for the case of the standard inner product there exists a complete rounding error analysis for all main orthogonalization schemes, the numerical properties of the schemes with a non-standard inner product are much less understood. We will formulate results on the loss of orthogonality and on the factorization error for all previously mentioned orthogonalization schemes.

This contribution is joint work with Jiří Kopal (Technical University Liberec), Miroslav Tůma a nd Alicja Smoktunowicz (Warsaw University of Technology).

Seiji Fujino
Research Institute for Information Technology, Kyushu University, Japan

A proposal of Multi-Restarts type of Look-Back GMRES(k) methods

Monday, 22.08.2011, 17:20 - 17:40, Room to be filled in later by organizers

Look-Back GMRES(k) method which determines an initial guess by an approximate solution vector obtained at the previous one restart was proposed by Imakura et al.[2010]. Their numerical experiments clarified that convergence rate of Look-Back GMRES(k) method is much better than that of the original GMRES(k) method. In this article, we extend their Look-Back GMRES(k) method by using approximate solution vectors obtained at the previous multi-restarts ($= m$) for determining an initial guess, and improve convergence rate of Look-Back GMRES(k) method. We refer to Multi-Restarts type of Look-Back GMRES(k) method. Through numerical experiments, it will be made clear that MR_LBGMRES(k = 40, m) method outperforms compared with the conventional restarted GMRES(k = 40) and the original LBGMRES(k = 40) methods.

This contribution is joint work with Yusuke Onoue (Kyushu University, Japan).

Daniel B. Szyld
Temple University, Philadelphia, USA

Short-term-recurrence method (and preconditioner) for nearly-Hermitian linear systems

Monday, 22.08.2011, 17:40 - 18:00, Room to be filled in later by organizers

We introduce a new short-term-recurrence Krylov subspace method for the solution of $n \times n$ linear systems in which the the skew-Hermitian part of the coefficient matrix is of low rank ($s \ll n$). Matrices of this form include discretizations of integral equations derived from wave scattering applications (Lippmann-Schwinger operators) as well as path following methods. Such a linear system can be interpreted as a Schur complement of a larger $(n+s) \times (n+s)$ system, and we can apply the Sherman-Morrison-Woodbury identity to solve this larger system with great savings in storage and computational effort. Most of the effort is spent solving s Hermitian systems. We call this the Schur complement method. Implicitly, we can approximate the skew-Hermitian part of the matrix in a Krylov subspace. We can then apply the Schur complement method as a flexible preconditioner. We present numerical results demonstrating competitiveness of the the new method, and of the new preconditioner when used with flexible GMRES.

This contribution is joint work with Mark Embree (Rice), Josef A. Sifuentes (NYU), Kirk Soodhalter (Temple), and Fei Xue (Temple).

Yimin Wei
Fudan University, P.R. China

Convergence of General Nonstationary Iterative Methods for Solving Singular Linear Equations

Tuesday, 23.08.2011, 18:00 - 18:20, Room to be filled in later by organizers

In this talk, we investigate the convergence of the general nonstationary iterative methods for solving consistent singular linear equations, and we discuss relations of general stationary results and ours. We utilize the quotient convergence to prove the convergence of the two-stage iterative algorithms for solving the consistent singular Hermitian positive semidefinite linear equations.

This contribution is joint work with Xinghua Shi and Wen Zhang (Fudan University, P.R. China).

Jesse Barlow
The Pennsylvania State University

Block Gram–Schmidt Algorithms

Monday, 22.08.2011, 18:20 - 18:40, Room to be filled in later by organizers

The talk discusses reorthogonalized block classical Gram–Schmidt algorithms. These algorithms are useful in developing BLAS–3 versions of orthogonal factorization in the implementation of Krylov space methods and in modifying an existing orthogonal decomposition. Algorithms are given for three contexts.
The first is the "standard case", that for factoring a full column rank matrix A into $A = QR$ where Q is left orthogonal (has orthonormal columns) and R is upper triangular and nonsingular. There it is shown that, with appropriate assumptions on the diagonal blocks of R, the algorithm, when implemented in floating point arithmetic with machine unit ε_M, produces Q and R such that $\|I - Q^T Q\|_2 = O(\varepsilon_M)$ and $\|A - QR\|_2 = O(\varepsilon_M \|A\|_2)$.
The second context is when the diagonal blocks are allowed to be singular or very ill-conditioned. A strategy for using rank–revealing decompositions to deal with that contingency is given that yields similar bounds to those for the first context. The third context is block downdating, the problem of deleting a number of samples from a least square problem.

This contribution is joint work with Alicja Smoktunowicz (Warsaw Univerisity of Technology, Warsaw).

Zdeněk Strakoš
Charles University in Prague, Czech Republic

On the continuous problem context of matrix computations in solving boundary value problems

Tuesday, 23.08.2011, 15:30 - 15:50, Room to be filled in later by organizers

In numerical solution of partial differential equation boundary value problems one has to deal with the following hierarchy of problems: the original continuous problem, the discretized problem where the approximate solution is restricted to some particular finite dimensional functional subspace and the algebraic problem where the coefficients determining the approximate solution are to be computed by solving the system of linear algebraic equations. The goal is to get an acceptable approximation to the solution of the original continuous problem. Here the acceptability refers to the mathematical modeling level and the error is measured in the continuous functional space. This implies that the measures of the algebraic error must take into account the original continuous problem, and the cost of algebraic computations can be affected or even determined via the approximation error measured in the continuous functional space. We will consider stopping criteria for iterative solvers and present the difficulties on examples.

This contribution is a joint work with Jörg Liesen (TU Berlin, Germany).

Miroslav Tůma
Institute of Computer Science, Academy of Sciences of the Czech Republic

Mixed direct-inverse decompositions and applications

Tuesday, 23.08.2011, 15:50 - 16:10, Room to be filled in later by organizers

Incomplete LU and Cholesky decompositions are basic building blocks of many preconditioning strategies to solve large and sparse systems of linear equations. While their inverse counterparts were considered also a long time ago, they started to be used in linear solvers just recently. In many cases it is computationally viable to compute both of them at the same time. They can be then used for mutual monitoring and improvements in their quality. The talk will discuss results of some recent research along this line.

Jörg Liesen
TU Berlin, Institute of Mathematics

On the convergence of GMRES for a convection-diffusion model problem

Tuesday, 23.08.2011, 16:10 - 16:30, Room to be filled in later by organizers

In this talk we will consider a standard model problem in the area of convection-diffusion problems, its discretisation on a uniform grid with bilinear finite elements by the streamline upwind Petrov-Galerkin (SUPG) method, and the solution of the corresponding discretised system by the GMRES method.
The GMRES residual norm curves for this model problem typically display two distinct phases of convergence: a slow initial phase followed by a second phase of convergence acceleration. The acceleration in the second phase appears to be faster when the parameters in the model problem yield a "more nonnormal" discretised operator in the sense that its eigenvector matrix is more ill-conditioned.
This counterintuitive observation can hardly be explained by standard GMRES convergence bounds. The main idea advocated in this talk is that the convergence bounds should reflect the interplay between eigenvalues/eigenvectors and the initial residual. Using such bounds in the context of the convection-diffusion model problem allows to explain why the conditioning of the eigenvectors plays (almost) no role for the speed of acceleration in the second phase. Such bounds can be of general interest beyond their application to the this model problem.
This contribution is joint work with Jurjen Duintjer Tebbens (Czech Academy of Sciences) and Zdeněk Strakoš (Charles University in Prague).

Jens-Peter M. Zemke
Institut für Numerische Simulation, Technische Universität Hamburg-Harburg

IDR: A new generation of Krylov subspace methods?

Monday, 22.08.2011, 16:30 - 16:50, Room to be filled in later by organizers

We briefly review some recent Krylov subspace methods from the class of Induced Dimension Reduction (IDR) methods, originally developed by Peter Sonneveld between 1976–1979, and extended substantially with Martin van Gijzen in 2006/2007. We focus on the last developments, mainly on IDRSTAB [Gerard L.G. Sleijpen and Martin B. van Gijzen, *Exploiting BiCGstab*(ℓ) *strategies to induce dimension reduction*. SIAM J. Sci. Comput. Vol. 32, No. 5, pp. 2687-2709, 2010] and IDREIG [Martin H. Gutknecht and Jens-Peter M. Zemke, *Eigenvalue computations based on IDR*, Bericht 145, TUHH, Institute of Numerical Simulation, 2010]. We compare our findings on the numerical stability and convergence behavior with those of other Krylov subspace methods.

This contribution is joint work with Olaf Rendel and Anisa Rizvanolli (both TU Hamburg-Harburg, Germany).

CS2: Numerical Methods for Eigenvalue Problems

	CS2.1: Numerical Methods for Eigenvalue Problems (PART I)	
Tuesday, 23.08.2011	Chair: 2.1	**Room:**
17:00 - 17:20	**Ming Zhou**	
	Convergence analysis of gradient iterations for the Rayleigh quotient	p. 107
17:20 - 17:40	**Tsung-Ming Huang**	
	Structure-Preserving Arnoldi-type Algorithms for Solving Palindromic Quadratic Eigenvalue Problems in Leaky Surface Wave Propagation	p. 107
17:40 - 18:00	**Elias Jarlebring**	
	Invariant pairs associated with the infinite Arnoldi method for nonlinear eigenvalue problems	p. 108
18:00 - 18:20	**Jeroen De Vlieger**	
	A subspace projection method for maximizing the smallest eigenvalue of parameterized generalized eigenvalue problems	p. 108
18:20 - 18:40	**David S. Watkins**	
	Generalizing Francis's implicitly-shifted QR algorithm: The never-ending saga	p. 109
	CS2.2: Numerical Methods for Eigenvalue Problems (PART II)	
Thursday, 25.08.2011	Chair: 2.2	**Room: SN19.1**
17:40 - 18:00	**Bor Plestenjak**	
	Numerical methods for nonlinear two-parameter eigenvalue problems	p. 109

- to be continued -

CS2.2: Numerical Methods for Eigenvalue Problems (PART II - continuation)

Thursday, 25.08.2011	Chair: 2.2	**Room: SN19.1**
18:00 - 18:20	**Andrej Muhič**	
	On a non-regular two-parameter eigenvalue problem	p. 110
18:20 - 18:40	**Shu-Ming Chang**	
	Computational Methods in Multi-Component Bose-Einstein Condensates	p. 110

- end of session -

Ming Zhou
Universität Rostock, Germany

Convergence analysis of gradient iterations for the Rayleigh quotient

Tuesday, 23.08.2011, 17:00 - 17:20, Room to be filled in later by organizers

Gradient type methods for the Rayleigh quotient can be used to compute some of the smallest eigenvalues and the associated eigenvectors of symmetric matrices. The benefit of these methods is that they can successfully be applied to extremely large matrices, which are e.g. derived from the finite element discretization of elliptic operator eigenvalue problems. Gradient type methods can converge very fast, if the gradients are considered with respect to a proper geometry. The topic of this talk is to derive and to present convergence estimates for the steepest descent/ascent gradient iterations using either Euclidean gradients or A-gradients. For the A-gradient steepest descent iteration the convergence factor does not depend on the discretization parameter. The main tools of our analysis are curve differentiation and optimization on ellipses.

This contribution is joint work with Klaus Neymeyr (Universität Rostock, Germany) and Evgueni Ovtchinnikov (University College London, UK).

Tsung-Ming Huang
Department of Mathematics, National Taiwan Normal University, Taiwan.

Structure-Preserving Arnoldi-type Algorithms for Solving Palindromic Quadratic Eigenvalue Problems in Leaky Surface Wave Propagation

Tuesday, 23.08.2011, 17:20 - 17:40, Room to be filled in later by organizers

We study the T-palindromic quadratic eigenvalue problems (TPQEP) arising from modeling leaky surface waves propagation in a acoustic resonator with infinitely many periodically arranged interdigital transducers. Periodic boundary condition proposed by Buchner is justified by the Bloch-Floquet Theory and is given to reduce the problem to a single cell problem. The constitution equations are discretized by finite element method with mesh refinement along the electrode interface and corners. Accurate and efficient solution of the TPQEP can be obtained using structure-preserving algorithm with a generalized T-skew-Hamiltonian implicity-restarted Arnoldi method. Our numerical results show that center of the stopping bands of the Leaky surface acoustic waves in crystals such as 64^o YX-$LiNbO_3$ and 36^o YX-$LiTaO_3$ obtained from the finite element model of the single cell problem is very close to the experimental data within an error about 1%. This paper reports on the successful application of the structure-preserving Arnoldi-type algorithms.

This contribution is joint work with Wen-Wei Lin (National Taiwan University, Taiwan) and Chin-Tien Wu (National Chiao Tung University, Taiwan).

Elias Jarlebring
KU Leuven

Invariant pairs associated with the infinite Arnoldi method for nonlinear eigenvalue problems

Tuesday, 23.08.2011, 17:40 - 18:00, Room to be filled in later by organizers

In recent works we have proposed an Arnoldi method (called the *infinite Arnoldi method*) for the nonlinear eigenvalue problem (NEP),

$$\lambda B(\lambda)x = x,$$

based on the operator $\mathcal{B}$ with action $(\mathcal{B}\varphi)(\theta) := \int_0^\theta \varphi(\theta)\,d\theta + \left(B(\frac{d}{d\theta})\varphi\right)(0)$, which reciprocal eigenvalues coincide with the solutions to the NEP. Invariant pairs are often used to derive restarting techniques for Arnoldi-type methods. In this work we consider invariant pairs of the operator $\mathcal{B}$. These invariant pairs turn out to be equivalent to existing definitions of invariant pairs for nonlinear eigenvalue problems [Kressner, *A block Newton method for nonlinear eigenvalue problems*, Num. Math., 2009, 114(2):355-372]. Moreover, we show how the action of the operator $\mathcal{B}$ applied to an approximation of an invariant pair, can be carried out efficiently in finite-dimensional arithmetic.

This contribution is joint work with Wim Michiels (KU Leuven) and Karl Meerbergen (KU Leuven).

Jeroen De Vlieger
KULeuven

A subspace projection method for maximizing the smallest eigenvalue of parameterized generalized eigenvalue problems

Tuesday, 23.08.2011, 18:00 - 18:20, Room to be filled in later by organizers

In many applications, we are only interested in the smallest eigenvalue. In the presence of parameters x, we want to maximize the smallest eigenvalue over x. Consider the following parametrized symmetric generalized eigenvalue problem

$$(K + \sum_{i=1}^{p} x_i S_i)\vec{v} = \lambda(M + \sum_{i=1}^{p} x_i T_i)\vec{v}$$

where the parameters x_i are uncertainties characterized by intervals on which $M + \sum_i x_i T_i$ is positive definite resulting in real eigenvalues which depend continuously on x but may be non-differentiable.
Level set methods are fast, but can only solve problems with a single parameter, i.e. $p = 1$. We develop a subspace projection method that exhibits equally fast convergence but which can be extended to $p > 1$. In each iteration λ_1 and a corresponding eigenvector $\vec{v}$ are computed for a specific x. $\vec{v}$ is then used to expand the subspace. And x is determined as the solution of the projected problem, which in turn also requires an iterative method that uses projection onto single vectors.

This contribution is joint work with Karl Meerbergen (KULeuven)

David S. Watkins
Washington State University

Generalizing Francis's implicitly-shifted QR algorithm: The never-ending saga

Tuesday, 23.08.2011, 18:20 - 18:40, Room to be filled in later by organizers

R. Vandebril recently proposed a large family of condensed forms that includes the Hessenberg, inverse-Hessenberg, and CMV forms as special cases. He showed how to obtain these forms and how to implement explicit and implicit QR-like algorithms on them. More recently we have shown how to implement implicit QR-like iterations of arbitrary degree, and we have developed the convergence theory of these algorithms. The condensed form evolves over the course of the iterations in a way that can be controlled. For example, Hessenberg form can be transformed to CMV or inverse-Hessenberg form over the course of many iterations. This capability of controlling the nature of the condensed form also allows some scope for manipulating the convergence rate.

This contribution is joint work with Raf Vandebril.

Bor Plestenjak
Department of Mathematics, University of Ljubljana, Slovenia

Numerical methods for nonlinear two-parameter eigenvalue problems

Thursday, 25.08.2011, 17:40 - 18:00, Room to be filled in later by organizers

In a nonlinear two-parameter eigenvalue problem (NMEP) we are searching for a pair (λ,μ) and nonzero vectors x_1, x_2, such that

$$\begin{aligned} F_1(\lambda,\mu)x_1 &= 0, \\ F_2(\lambda,\mu)x_2 &= 0, \end{aligned}$$

where $F_i : \mathbb{C}^2 \to \mathbb{C}^{n_i\times n_i}$ is a nonlinear operator for $i = 1, 2$. In such case (λ,μ) is an eigenvalue and $x_1 \otimes x_2$ is the corresponding eigenvector. We assume that the problem is regular, i.e., $\det(F_i(\lambda,\mu)) \not\equiv 0$ for $i = 1, 2$.
NMEP can be viewed as a generalization of the nonlinear eigenvalue problem (NEP) as well as a generalization of the algebraic two-parameter eigenvalue problem (MEP). We will show that many numerical methods and theoretical results for NEP and MEP can be generalized to NMEP.
An example of a NMEP is a quadratic two-parameter eigenvalue problem (QMEP) which appears in the study of linear time-delay systems for the single delay case.

Andrej Muhič
IMFM and Department of Mathematics, University of Ljubljana, Slovenia

On a non-regular two-parameter eigenvalue problem

Thursday, 25.08.2011, 18:00 - 18:20, Room to be filled in later by organizers

We consider *a singular algebraic two-parameter eigenvalue problem* (W)

$$\begin{aligned} W_1(\lambda,\mu)x_1 := (A_1 + \lambda B_1 + \mu C_1)x_1 &= 0, \\ W_2(\lambda,\mu)x_2 := (A_2 + \lambda B_2 + \mu C_2)x_2 &= 0, \end{aligned}$$

where $A_i, B_i,$ and C_i are such $n_i \times n_i$ matrices, that all linear combinations of *operator determinants* $\Delta_0 = B_1 \otimes C_2 - C_1 \otimes B_2$, $\Delta_1 = C_1 \otimes A_2 - A_1 \otimes C_2$, and $\Delta_2 = A_1 \otimes B_2 - B_1 \otimes A_2$ are singular.

We extend the theory and the algorithm from [A. Muhič and B. Plestenjak, *On the singular two-parameter eigenvalue problem*, Electron. J. Linear Algebra 18 (2009) 420–437] to the *non-regular* case, where $\det(W_i(\lambda,\mu)) \equiv 0$ for $i = 1$ or $i = 2$. We show that the finite regular eigenvalues of (W), which are defined by the rank drop, are related to the finite regular eigenvalues of the coupled singular generalized eigenvalue problem $\Delta_1 z - \lambda\Delta_0 z$, $\Delta_2 z - \mu\Delta_0 z$. We introduce the minimal common reducing subspace for two matrix pencils and present a numerical algorithm that can be applied to a general singular two-parameter eigenvalue problem.
This is joint work with Bor Plestenjak (University of Ljubljana)

Shu-Ming Chang
National Chiao Tung University, Taiwan

Computational Methods in Multi-Component Bose-Einstein Condensates

Thursday, 25.08.2011, 18:20 - 18:40, Room to be filled in later by organizers

In this talk, we propose two iterative methods (Jacobi-type iteration and Gauss-Seidel-type iteration) and one continuation method (continuation block successive overrelaxation Lanczos-Galerkin method) for the computation of positive bound states of the time-independent vector Gross-Pitaevskii equation which describes a multi-component Bose-Einstein condensate. A discretization of the vector Gross-Pitaevskii equation leads to a nonlinear algebraic eigenvalue problem. We prove that the Gauss-Seidel-type iteration converges locally and linearly to a solution of the nonlinear algebraic eigenvalue problem if and only if the associated minimized energy functional problem has a strictly local minimum. Numerical experience shows that the Gauss-Seidel-type iteration converges much faster than Jacobi-type iteration and converges globally within 10 to 20 steps. Numerical results show that various positive bound states of a two/three-component Bose-Einstein condensate are solved efficiently and reliably by the continuation block successive overrelaxation Lanczos-Galerkin method.

This contribution is a joint work with Yuen-Cheng Kuo (National University of Kaohsiung, Taiwan), Wen-Wei Lin (National Taiwan University, Taiwan) and Shih-Feng Shieh (National Taiwan Normal University, Taiwan).

CS3: Singular Values and Least Squares

	CS3: Singular Values and Least Squares	
Friday, 26.08.2011	Chair: 3	**Room:**
15:30 - 15:50	**Johan A. Ceballos**	
	Accurate solution of the least squares problems via rank-revealing decomposition	p. 112
15:50 - 16:10	**Iveta Hnětynková**	
	Stopping criteria for the LSQR method based on revealing the noise level in the data	p. 112
16:10 - 16:30	**Jose Mas**	
	BIF preconditioner applied to least squares problems	p. 113
16:30 - 16:50	**Huaian Diao**	
	On Condition Numbers for Constrained Linear Least Squares Problems	p. 113
16:50 - 17:10	**João Filipe Queiró**	
	Note on low rank updates of singular values	p. 114

- end of session -

Johan A. Ceballos
Universidad Carlos III de Madrid

Accurate solution of the least squares problems via rank-revealing decomposition

Friday, 26.08.2011, 15:30 - 15:50, Room to be filled in later by organizers

Least squares problems $Ax \approx b$ where the matrix A has some particular structure tend to arise frequently in applications. Very often structured matrices have huge condition numbers $\kappa(A) = \|A^{-1}\| \, \|A\|$ and, therefore, standard algorithms fail to compute accurate solutions of $Ax \approx b$. In this work, we introduce a framework that allows us to solve accurately many classes of structured least squares problems independently of the condition number of A and with cost $O(n^3)$. The approach in this work relies on computing first an accurate rank-revealing decomposition of A, an idea that has been widely used in the last decades to compute singular value and eigenvalue decompositions of structured matrices with high relative accuracy, and more recently, to compute accurate solution of structured linear systems. Among others, it can be applied to Cauchy and Vandermonde matrices, with any distribution of nodes, i.e., without requiring A to be totally positive, and Graded matrices, diagonal scalings of a well-conditioned matrix.

This contribution is joint work with Froilán M. Dopico (Universidad Carlos III de Madrid, Spain) and Juan M. Molera (Universidad Carlos III de Madrid, Spain).

Iveta Hnětynková
Charles University in Prague, Faculty of Mathematics and Physics

Stopping criteria for the LSQR method based on revealing the noise level in the data

Friday, 26.08.2011, 15:50 - 16:10, Room to be filled in later by organizers

In this contribution we consider a linear ill-posed problem $Ax \approx b$ with a right-hand side b contaminated by unknown *white noise*, $b = b_{exact} + b_{noise}$. The LSQR method belongs among popular regularization techniques for solving such problems. In the hybrid LSQR, first, the original problem is projected onto a lower dimensional Krylov subspace using the bidiagonalization (outer regularization). The projected problem may inherit a part of the ill-posedness of the original problem, and therefore some form of inner regularization is applied. Stopping criteria for the whole process are usually based on the properties of the projected (small) problem.
It was shown in [I. Hnětynková, M. Plešinger, Z. Strakoš, The regularizing effect of the Golub-Kahan iterative bidiagonalization and revealing the noise level in the data, BIT **49**, pp. 669–696 (2009)] that the information from the Golub-Kahan iterative bidiagonalization can be used for *estimating the unknown noise level* in the data. In this presentation we study how such information can further be used for improving a regularized solution.

This contribution is joint work with Martin Plešinger (ETH Zurich, Switzerland) and Zdeněk Strakoš (MFF UK and ICS CAS, Czech Republic).

Jose Mas
Institut de Matemàtica Multidisciplinar, Universitat Politècnica de València

BIF preconditioner applied to least squares problems

Friday, 26.08.2011, 16:10 - 16:30, Room to be filled in later by organizers

The application of the improved BIF algorithm to compute preconditioners for the iterative solution of least squares problems is analysed. The algorithm computes simultaneously the L and U factors and their inverses L^{-1} and U^{-1} of a matrix using the Inverse Sherman-Morrison decomposition. To construct a preconditioner, dropping rules are imposed on the process. and balanced incomplete factors are obtained. Numerical experiments on test matrices are given.

This contribution is joint work with R. Bru (UPV, Spain), J. Marín (UPV, Spain) and M. Tůma (ICS, Czech Republic).

Huaian Diao
Northeast Normal University, Renmin Street No. 5268, Changchun, 130024, P.R. of China

On Condition Numbers for Constrained Linear Least Squares Problems

Friday, 26.08.2011, 16:30 - 16:50, Room to be filled in later by organizers

Condition numbers are important in numerical linear algebra, who can tell us the posterior error bounds for the computed solution. Classical condition numbers are normwise, but they ignore the input data sparsity and/or scaling. Componentwise analysis had been introduced, which gives a powerful tool to study the perturbations on input and output data regarding on the sparsity and scaling. In this paper under componentwise perturbation analysis we will study the condition numbers for constrained linear least squares problems. The obtained expressions of the condition numbers avoid the explicit forming Kronecker products, which can be estimated by power methods efficiently. Numerical examples show that our condition numbers can give better error bounds.

João Filipe Queiró
Universidade de Coimbra, Portugal

Note on low rank updates of singular values

Friday, 26.08.2011, 16:50 - 17:10, Room to be filled in later by organizers

This talk is a comment on the paper [D. Chu and M. Chu, "Low rank update of singular values", *Mathematics of Computation* 75 (2006), no. 255, 1351-1366]. We survey the literature and unify and simplify some of the results in that paper.

CS4: Matrix Functions and Equations

CS4.1: Matrix Functions and Equations (PART I)

Monday, 22.08.2011	Chair: 4.1	**Room:**
15:30 - 15:50	**Luis Verde-Star** *Computation of the matrix exponential using the dynamic solution*	p. 117
15:50 - 16:10	**Krystyna Ziętak** *Properties of the Padé family of iterations for computing the matrix sign and sector functions*	p. 117
16:10 - 16:30	**Albrecht Böttcher** *The algebraic Riccati equation with Toeplitz matrices as coefficients*	p. 118
16:30 - 16:50	**Eric King-wah Chu** *Solving Large-Scale Algebraic Riccati Equations by Doubling*	p. 118

CS4.2: Matrix Functions and Equations (PART II)

Monday, 22.08.2011	Chair: 4.2	**Room:**
17:00 - 17:20	**Yueh-Cheng Kuo** *Complex symmetric stabilizing solution of the nonlinear matrix equation* $X + A^{\top} X^{-1} A = Q$	p. 119
17:20 - 17:40	**Froilán M. Dopico** *Consistency and efficient solution of the Sylvester equation for congruence:* $AX + X^{\star} B = C$	p. 119

- to be continued -

CS4.2: Matrix Functions and Equations (PART II - continuation)

Monday, 22.08.2011	Chair: 4.2	**Room:**
17:40 - 18:00	**Shinya Miyajima** *Enclosing solutions in Sylvester equations*	p. 120
18:00 - 18:20	**Ninoslav Truhar** *Optimization of the solution of the Sylvester equation and applications*	p. 120
18:20 - 18:40	**Martin Plešinger** *Preconditioned Low-rank Krylov Subspace Solvers for Lyapunov Equations*	p. 121

- end of session -

Luis Verde-Star
Universidad Autónoma Metropolitana, Mexico City

Computation of the matrix exponential using the dynamic solution

Monday, 22.08.2011, 15:30 - 15:50, Room to be filled in later by organizers

We use some results from [L. Verde-Star, Functions of matrices, Linear Algebra Appl. 406 (2005) 285–300.] to construct algorithms for the computation of $exp(tA)$, where A is a square matrix and t is a real number in an interval $[a, b]$. Our algorithm uses the coefficients of a monic polynomial $w(z)$ such that $w(A) = 0$, and the formula $\exp(tA) = \sum_{k=0}^{n} g_k(t)w_k(A)$. The w_k are the Horner polynomials of w, $g_n(t)$ is the dynamic solution associated with w, and the other g_k are obtained from g_n by repeated differentiation. We use scaling with respect to the coefficients of w, excluding the leading coefficient, and approximate g_n with a truncated Taylor series to get a function $F(tA)$ that approximates $\exp(tA)$. The algorithm gives also the norm of $F'(tA) - AF(tA)$, which is close to the norm of $E(tA) - F(tA)$, where $E(tA)$ is the approximation computed by Maple with precision of 100 digits. For 20×20 matrices our method computes $F(tA)$ for 30 values of t in the same time that Maple computes $\exp(tA)$ for a single value of t.

This contribution is joint work with J.R. Mandujano (Escuela Superior de Cómputo, IPN, Mexico).

Krystyna Ziętak
Wrocław University of Technology, Poland

Properties of the Padé family of iterations for computing the matrix sign and sector functions

Monday, 22.08.2011, 15:50 - 16:10, Room to be filled in later by organizers

In the talk we focus on regions of convergence of the Padé family of iterations proposed by Kenney and Laub for computing the matrix sign function and of the Padé family of iterations introduced by Laszkiewicz and Ziętak for the matrix sector function. For this purpose we investigate the properties of the Padé approximants to hypergeometric functions, on which the iterations are based. We determine location of poles of the Padé approximants and we prove that all coefficients of the power expansions of the reciprocals of the denominators of the Padé approximants are positive.

This contribution is joint work with O. Gomilko (the Copernicus University, Toruń, Poland) and F. Greco (Università di Perugia, Italy).

Albrecht Böttcher
Technische Universität Chemnitz, Germany

The algebraic Riccati equation with Toeplitz matrices as coefficients

Monday, 22.08.2011, 16:10 - 16:30, Room to be filled in later by organizers

It is shown that, under appropriate assumptions, the continuous algebraic Riccati equation with Toeplitz matrices as coefficients has Toeplitz-like solutions. Both infinite and sequences of finite Toeplitz matrices are considered, and also studied is the finite section method, which consists in approximating infinite systems by large finite truncations. The results are proved by translating the problem into C^*-algebraic language and by using theorems on the Riccati equation in general C^*-algebras. The talk may serve as another illustration of the usefulness of C^*-algebra techniques in matrix theory and numerical analysis.

Eric King-wah Chu
Monash University, Australia

Solving Large-Scale Algebraic Riccati Equations by Doubling

Monday, 22.08.2011, 16:30 - 16:50, Room to be filled in later by organizers

We consider the solution of large-scale algebraic Riccati equations with (numerically) low-ranked solutions. For the discrete-time case, the structure-preserving doubling algorithm will be adapted for the sparsity and the low-ranked structures in the algebraic Riccati equation. For the continuous-time case, the algebraic Riccati equation will be first treated with the Cayley transform before doubling is applied. With n being the dimension of the algebraic Riccati equations, the resulting algorithms are of a feasible $O(n)$ complexity. Some numerical results will be presented. As an example, a DARE of dimension $n = 79841$, with 3.19 billion variables in the solution X, was solved using MATLAB on a MacBook Pro to machine accuracy within 1,100 seconds.

This contribution is joint work with Tiexiang Li (Southeast University, China) and Wen-Wei Lin (National Taiwan University, Taiwan).

Yueh-Cheng Kuo
National University of Kaohsiung, Taiwan

Complex symmetric stabilizing solution of the nonlinear matrix equation $X+A^\top X^{-1}A = Q$

Monday, 22.08.2011, 17:00 - 17:20, Room to be filled in later by organizers

We study the matrix equation $X + A^\top X^{-1}A = Q$, where A is a complex square matrix and Q is complex symmetric. Special cases of this equation appear in Green's function calculation in nano research and also in the vibration analysis of fast trains. In those applications, the existence of a unique complex symmetric stabilizing solution has been proved using advanced results on linear operators. The stabilizing solution is the solution of practical interest. In this talk we will give an elementary proof of the existence for the general matrix equation, under an assumption that is satisfied for the two special applications. Moreover, our new approach here reveals that the unique complex symmetric stabilizing solution has a positive definite imaginary part. The unique stabilizing solution can be computed efficiently by the doubling algorithm.

This contribution is joint work with Chun-Hua Guo (University of Regina, Canada) and Wen-Wei Lin (National Taiwan University, Taiwan).

Froilán M. Dopico
Department of Mathematics. Universidad Carlos III de Madrid (Spain)

Consistency and efficient solution of the Sylvester equation for congruence: $AX+X^\star B = C$

Monday, 22.08.2011, 17:20 - 17:40, Room to be filled in later by organizers

We consider the matrix equation $AX + X^\star B = C$, where the matrices A and B have sizes $m \times n$ and $n \times m$, respectively, the size of the unknown X is $n \times m$, and $(\cdot)^\star$ denotes either the transpose or the conjugate transpose of a matrix. We provide, first, a necessary and sufficient condition for the existence of solutions in any field. This condition is in the spirit of the well-known Roth's criterion for the existence of solutions of the standard Sylvester equation. In addition, we present, in the real or complex square case $m = n$, a generalized Schur algorithm to solve the equation in $O(n^3)$ flops when the solution is unique. The equation $AX + X^\star B = C$ is connected with palindromic eigenvalue problems and some particular cases in the complex field have attracted recently the attention of several authors. Byers, Kressner, Schröder and Watkins have established for the square case necessary and sufficient conditions for the existence of a unique solution for every right-hand side, while De Terán and Dopico have solved the homogeneous equations $AX + X^\star A = 0$ and studied their relationship with orbits of matrices under the action of $\star$-congruence.

This contribution is joint work with Fernando De Terán (Universidad Carlos III de Madrid (Spain)).

Shinya Miyajima
Gifu University, Japan

Enclosing solutions in Sylvester equations

Monday, 22.08.2011, 17:40 - 18:00, Room to be filled in later by organizers

In this presentation, we consider numerically enclosing solutions in Sylvester equations $AX + XB = C$, where A, B and C are known $m \times m$, $n \times n$ and $m \times n$ complex matrices, respectively. Sylvester equations appear in many important problems in science and technology, e.g. control theory, model reduction, image processing and so forth.
Recently Frommer and Hashemi [Frommer, A. and Hashemi, B., Verified error bounds for solutions of Sylvester matrix equations, Linear Algebra Appl., in press] proposed an algorithm for enclosing solutions in Sylvester equations. This algorithm returns a complex interval matrix including the exact solution X^* by creating candidate sets and examining whether the sets include X^* or not, and is pioneering work for enclosing X^* with cubic complexity.
The purpose of this presentation is to propose an algorithm for enclosing X^* by computing *directly* a real $m \times n$ matrix X^ε satisfying $|\tilde{X} - X^*| \leq X^\varepsilon$, where $\tilde{X}$ denotes a numerically computed solution and $|M| := \{|M_{ij}|\}$ for a matrix $M = \{M_{ij}\}$. Similarly to the above algorithm, the complexity of this algorithm is cubic when A and B are diagonalizable. We present theory for computing X^ε, and finally report some numerical examples to show the property of the proposed algorithm.

Ninoslav Truhar
Department of Mathematics, University of Osijek, Croatia

Optimization of the solution of the Sylvester equation and applications

Monday, 22.08.2011, 18:00 - 18:20, Room to be filled in later by organizers

We consider a parameter-dependent Sylvester equation of the form

$$(A_0 - vC_1(p_1)C_2(p_2)^T)X(v,p,q) + X(v,p,q)(B_0 - vD_1(q_1)D_2(q_2)^T) = E\,,$$

where A_0 is $m \times m$, B_0 is $n \times n$, C_1 and C_2 are $m \times r_1$, D_1 and D_2 are $n \times r_2$ and X, E are $m \times n$ matrices.
We will present an algorithm for optimization of the solution $X(v,p,q)$ of the above Sylvester equation, where $v \in \mathbb{R}$ and $p \equiv [p_1, p_2]$, $q \equiv [q_1, q_2]$ are indices which determine the form of matrices C_i and D_i in the way that columns p_i, q_i of matrices $C_i(p_i)$, $D_i(q_i)$, respectively, correspond to the predetermined linearly independent vectors.
Optimization will be done with respect to two different optimization criteria: minimal value of the trace of $X(v,p,q)$ and minimal value of the Frobenius norm of $X(v,p,q)$. A special case of this problem is a very important problem of optimal viscosity and position of dampers in mechanical systems.

This contribution is joint work with Ivana Kuzmanović (Department of Mathematics, University of Osijek, Croatia).

Martin Plešinger
Seminar for Applied Mathematics, ETH Zurich, Switzerland

Preconditioned Low-rank Krylov Subspace Solvers for Lyapunov Equations

Monday, 22.08.2011, 18:20 - 18:40, Room to be filled in later by organizers

Our contribution is focused on the investigaton of the behavior of Krylov subspace methods for solving large Lyapunov equations $AX + XA^T = -BB^T$, where $B \in R^{n \times r}$ and $r \ll n$. In practice, a direct solution of a large Lyapunov equation is not possible and therefore an iterative approach has to be used. Krylov subspace methods, in particular the conjugate gradient (CG) methods, offer a fast and robust way for solving classical linear systems. The CG method adapted to the Lyapunov equation *preserves the structure* of the problem, which can be further exploited in so called *low-rank truncation (LRT)*. For large systems, the LRT technique can significantly decrease the number of operations and therefore speed up the computation. However, to avoid slow convergence the CG method needs to be preconditioned. We investigate several preconditioners (SSOR, ADI, sign iteration using hierachical and semiseparable matrices, multigrid-based preconditioner) for this purpose. The whole concept can be extended to tensors which are useful for parameter-dependent Lyapunov equations arising from model reduction of parametrized control systems.

This contribution is joint work with Christine Tobler (ETH Zurich, Switzerland) and Daniel Kressner (ETH Zurich, Switzerland).

CS5: Model and Dimension Reduction

	CS5: Model and Dimension Reduction	
Thursday, 25.08.2011	Chair: 5	**Room:**
17:40 - 18:00	**Antonio Cosmin Ionita** *Model Order Reduction of Parametrized Systems*	p. 123
18:00 - 18:20	**André Schneider** *Balanced Truncation for Descriptor Systems with Many Terminals*	p. 123
18:20 - 18:40	**Patrick Kürschner** *Dominant pole computation of MIMO second order systems*	p. 124

- end of session -

Antonio Cosmin Ionita
Rice University, USA

Model Order Reduction of Parametrized Systems

Thursday, 25.08.2011, 17:40 - 18:00, Room to be filled in later by organizers

In this talk, we address model order reduction of parametrized linear systems. We present the case of one-parameter systems, that is, the transfer function is a two-variable rational function, with the two variables being the complex frequency and the parameter. Our main goal is to construct accurate reduced order models of low complexity in both variables.
The key to our approach is the *two-variable rational interpolation* problem. We provide a novel solution to this problem by introducing the two-variable Loewner matrix. Interpolants are constructed directly from its kernel using Lagrange bases for the two-variable numerator and denominator polynomials.
Crucially, the rank of the Loewner matrix encodes the complexity (degree) of the original system. In addition, the singular values of the Loewner matrix give an error bound for our reduced models; more precisely, if the singular values present a fast decay, we can construct accurate reduced models. Therefore, our method provides a trade-off between accuracy and complexity: given a desired value for the error, we can automatically determine the complexity of the reduced model from the decay of the singular values. We showcase these results in a series of numerical examples.

This contribution is joint work with A.C. Antoulas (Rice University, USA).

André Schneider
MPI for Dynamics of Complex Technical Systems Magdeburg, Germany

Balanced Truncation for Descriptor Systems with Many Terminals

Thursday, 25.08.2011, 18:00 - 18:20, Room to be filled in later by organizers

The model reduction method introduced in [Benner, P. and Schneider, A.; *Balanced Truncation Model Order Reduction for LTI Systems with many Inputs or Outputs*, in A. Edelmayer: Proceedings of the 19th International Symposium on Mathematical Theory of Networks and Systems, 2010, ISBN/ISSN: 978-963-311-370-7] shows how to reduce linear time invariant (LTI) continuous time state space systems with either many inputs or many outputs using the well-known balanced truncation approach. We call this method balanced truncation for many terminals (BTMT). In this talk we generalize BTMT to descriptor systems of the form

$$\begin{aligned} E\dot{x}(t) &= Ax(t) + Bu(t), \qquad A, E \in \mathbb{R}^{n\times n}, B \in \mathbb{R}^{n\times m}, \\ y(t) &= Cx(t) + Du(t), \qquad C \in \mathbb{R}^{p\times n}, D \in \mathbb{R}^{p\times m}, \end{aligned}$$

where $m \in \mathcal{O}(n)$ and $p \ll n$, or vice versa. We explain how to obtain the reduced order model by solving one Lyapunov equation and using the Gauß-Kronrod quadrature to compute the needed projection matrices. We also discuss the case that E is singular and show numerical results.

This contribution is joint work with Peter Benner (MPI Magdeburg, Germany).

Patrick Kürschner
MPI Magdeburg

Dominant pole computation of MIMO second order systems

Thursday, 25.08.2011, 18:20 - 18:40, Room to be filled in later by organizers

Linear time invariant dynamical systems of second order arise frequently in many practical applications, e.g., in the vibration analysis of mechanical structures. They can be represented in the frequency domain by transfer functions of the form $H(s) = C(s^2M + sD + K)^{-1}B$. The dominant poles of $H(s)$ play an important role in modal approximation, where the original system is approximated using a special subset of eigentriplets of the quadratic matrix polynomial $Q(\lambda) = \lambda^2 M + \lambda D + K$. The computation of these eigenvalues and vectors relies on special eigenvalue algorithms for the underlying quadratic eigenvalue problem. For single-input-single-output systems, one candidate for this purpose is the subspace accelerated quadratic dominant pole algorithm [J. Rommes and N. Martins, "Computing Transfer Function Dominant Poles of Large-Scale Second-Order Dynamical Systems", *SIAM Journal on Scientific Computing*, vol. 30, no. 4, pp. 2137–2157, 2008]. Here we investigate the extension of this method to the multi-input-multi-output case and discuss various issues to improve its numerical reliability. Naturally, the approaches carry over to transfer functions involving arbitrary matrix polynomials, but also nonlinear matrix valued functions.

This contribution is joint work with Peter Benner (MPI Magdeburg, Germany) and Joost Rommes (NXP Eindhoven, Netherlands).

CS6: Generalized Inverses

	CS6.1: Generalized Inverses (PART I)	
Tuesday, 23.08.2011	Chair: 6.1	**Room:**
15:30 - 15:50	**Benjamin Jeffryes**	
	A new approach to generalized inverses	p. 126
15:50 - 16:10	**Xinghua Shi**	
	Convergence of Rump's Method for Computing Moore-Penrose Inverse	p. 126
16:10 - 16:30	**Marko D. Petković**	
	Iterative method for computing Moore-Penrose inverse based on Penrose equations	p. 127
16:30 - 16:50	**Dominik Stahl**	
	Superresolution using the lifting scheme and an adapted pseudoinverse	p. 127

	CS6.2: Generalized Inverses (PART II)	
Thursday, 25.08.2011	Chair: 6.2	**Room:**
17:40 - 18:00	**K.C. Sivakumar**	
	Generalized inverse positivity of interval matrices	p. 128
18:00 - 18:20	**Oskar Maria Baksalary**	
	On the projectors $\mathbf{A}\mathbf{A}^{\dagger}$ *and* $\mathbf{A}^{\dagger}\mathbf{A}$	p. 128
18:20 - 18:40	**Götz Trenkler**	
	On the matrix difference $\mathbf{I} - \mathbf{A}$	p. 129

- end of session -

Benjamin Jeffryes
Schlumberger Cambridge Research

A new approach to generalized inverses

Tuesday, 23.08.2011, 15:30 - 15:50, Room to be filled in later by organizers

Formulae for calculating generalized matrix inverses go back to Moore's work in 1920, but explicit, basis independent, formulae are only well known for special cases, such as full-rank rectangular matrices. I will show that given a rank r matrix M_{aA}, whose Hermitian product is Q_{ab} ($Q_{ab} = M_{aA}\bar{M}_b^A$), then for $k <= r$, a sequence of matrices ${}_kN$ may be defined by

$$ {}_kN_{aA} = \frac{k\bar{M}_{A[a}Q_b^{[b}Q_c^c \dots Q_{d]}^{d]}}{Q_{[f}^{[f}Q_g^g \dots Q_{h]}^{h]}} $$

(where there are $(k-1)$ copies of Q in the numerator and k in the denominator, and square brackets denote anti-symmetrization),and the generalized inverse of M is ${}_rN$. For $k < r$, the matrices ${}_kN$ have similar properties to inverses using reduced numbers of singular values but with the advantage of an analytic construction. $trace({}_kNM) = k$ and $\forall$ vectors v, $|{}_jNv| < |{}_kNv|$ if $j < k$. If M is full rank, but close to a matrix with reduced rank r, then ${}_rN$ will be close to the generalized inverse of the reduced rank matrix. This construction is particularly advantageous for obtaining inverse operators where both small singular values and noise are present.

Xinghua Shi
Fudan University, P.R. China

Convergence of Rump's Method for Computing Moore-Penrose Inverse

Tuesday, 23.08.2011, 15:50 - 16:10, Room to be filled in later by organizers

In this talk, we will extend Rump's method for computing the Moore-Penrose inverse of full rank but extremely ill-conditioned matrices.
We will introduce an iterative algorithm to computing the Moore-Penrose inverse with huge condition number. Our algorithm makes use of the INTALB toolbox developed by S.Rump to compute an accurate dot product calculation algorithm.
In our algorithm, we find that the choice of initial guess of the Moore-Penrose inverse of matrix A is very important. Suppose the initial matrix is $R_1 = (A + \Delta A)^\dagger$, we prove that if $\mathcal{R}(\Delta A^T) \subseteq \mathcal{R}(A^T)$, our algorithm is convergent. So that $R_1 = A^T$ is one of the best choice.
From the numerical example, the relative error of our algorithm can be smaller than 10^{-11} even if the condition number of the given matrix is about 10^{30}. This error is much smaller than the SVD based algorithms (such as truncated SVD and regularization method).

This contribution is joint work with Yimin Wei (Fudan University, Shanghai, P.R. China).

Marko D. Petković
University of Niš, Faculty of Sciences and Mathematics, Višegradska 33, 18000 Niš, Serbia

Iterative method for computing Moore-Penrose inverse based on Penrose equations

Tuesday, 23.08.2011, 16:10 - 16:30, Room to be filled in later by organizers

Based on Penrose equations (2) and (4), we developed an iterative method for computing Moore-Penrose inverse given by

$$X_{k+1} = (I - \beta X_k A)^* X_k + \beta X_k, \qquad X_0 = \beta A^*.$$

We discussed the convergence properties and gave expressions for the first-order and second-order error terms. We also discussed the instability of our and similar methods and proposed one stabilization method. Few numerical examples are shown to verify theoretical results.

This contribution is joint work with Predrag Stanimirović (University of Niš, Faculty of Sciences and Mathematics, Serbia).

Dominik Stahl
ITWM Kaiserslautern

Superresolution using the lifting scheme and an adapted pseudoinverse

Tuesday, 23.08.2011, 16:30 - 16:50, Room to be filled in later by organizers

We introduce a method for image superresolution, based on the lifting scheme, which can be used to design wavelets and to perform the discrete wavelet transform. A central task in our approach is to solve a least squares problem $\min_{x \in \mathbf{R}^n} \|Ax - b\|_2$ where $A \in \mathbf{R}^{m \times n}$ is rank-deficient. The minimal-norm solution obtained with the Moore-Penrose-inverse turns out to be not the choice, since it yields artefacts at the boundary of the high resolution image. Using extra information on the matrix A we construct a different pseudoinverse $A^{\#}$ which is much more appropriate to our problem and delivers better solutions.

This contribution is joint work with Tobias Damm (TU Kaiserslautern, Germany).

K.C. Sivakumar
Indian Institute of Technology Madras

Generalized inverse positivity of interval matrices

Thursday, 25.08.2011, 17:40 - 18:00, Room to be filled in later by organizers

For $B, C \in R^{m\times n}$, let $J = [B, C]$ be the set of all matrices A such that $B \leq A \leq C$, where the order is component wise. Krasnosel'skij',et. all '[Positive Linear Systems, Heldermann Verlag, Berlin]' and Rohn '[*Inverse-positive interval matrices*, Z. Ang. Math. Mech., 67, 1987]' have shown that if B and C are invertible with $B^{-1} \geq 0$ and $C^{-1} \geq 0$, then every $A \in J$ is invertible with $A^{-1} \geq 0$. In the talk, we present certain extensions of this result to the singular case. The nonnegativity of the usual inverses will be replaced by the nonnegativity of certain classes of generalized inverses. We also discuss possible extensions of these results to operators over general Banach spaces.

This contribution is joint work with M. Rajesh Kannan (Indian Institute of Technology Madras, India) and P. Veeramani (Indian Institute of Technology Madras, India).

Oskar Maria Baksalary
Adam Mickiewicz University, Poland

On the projectors $\mathbf{AA}^\dagger$ *and* $\mathbf{A}^\dagger\mathbf{A}$

Thursday, 25.08.2011, 18:00 - 18:20, Room to be filled in later by organizers

Two orthogonal projectors $\mathbf{AA}^\dagger$ and $\mathbf{A}^\dagger\mathbf{A}$, where $\mathbf{A}^\dagger$ stands for the Moore–Penrose inverse of a square complex matrix $\mathbf{A}$, are considered. Some properties of the pair of projectors, as well as their various functions, are already available in the literature, and these scattered results deal, for example, with their coincidence, commutativity, or nonsingularity of their difference. The present paper provides extensive investigations over the pair leading to new relevant results involving further functions of $\mathbf{AA}^\dagger$ and $\mathbf{A}^\dagger\mathbf{A}$. In consequence, several characteristics are established, which involve such fundamental notions as rank, range, null space, and eigenvalues. Special attention is paid to the relationships between various properties of the functions and known classes of matrices, such as range-Hermitian, disjoint range, spanning range, or nilpotent. The mathematical approach exploited is based on the particular partitioned representation of matrices originating from the singular value decomposition, which proved to be very powerful for the analysis. As a byproduct, a rich collection of useful properties of the representation is identified as well.

This contribution is joint work with Götz Trenkler (Dortmund University of Technology, Germany).

Götz Trenkler
Dortmund University of Technology, Germany

On the matrix difference $\mathbf{I} - \mathbf{A}$

Thursday, 25.08.2011, 18:20 - 18:40, Room to be filled in later by organizers

For an $n \times n$ complex matrix $\mathbf{A}$ and the $n \times n$ identity matrix $\mathbf{I}_n$, the difference $\mathbf{I}_n - \mathbf{A}$ is investigated. By exploiting a partitioned representation, several features of such a difference are identified. In particular, expressions for its Moore–Penrose inverse in some specific situations are established, and representations of the pertinent projectors are derived. Special attention is paid to the problem how certain properties of $\mathbf{A}$ and $\mathbf{I}_n - \mathbf{A}$ are related. The properties in question deal with known classes of matrices, such as GP, EP, partial isometries, bi-EP, normal, projectors, and nilpotent. An important part of the paper is devoted to demonstrating how to obtain representations of orthogonal projectors onto various subspaces determined by $\mathbf{A}$ and/or $\mathbf{I}_n - \mathbf{A}$. Several such representations are provided and a number of relevant conclusions originating from them are identified.

This contribution is joint work with Oskar Maria Baksalary (Adam Mickiewicz University, Poland).

CS7: Structured Matrices

	CS7.1: Structured Matrices (PART I)	
Monday, 22.08.2011	Chair: 7.1	**Room:**
15:30 - 15:50	**Isabel Gimenez** *Iterative determination of H-matrices and Irreducible Diagonal Blocks*	p. 132
15:50 - 16:10	**Susana Furtado** *On the Eigenvalues of Principal Submatrices of J-Normal Matrices*	p. 132
16:10 - 16:30	**Georgios Katsouleas** *Links on Imbedding Conditions for normal matrices*	p. 133
16:30 - 16:50	**Bruno Iannazzo** *Computing means of structured matrices*	p. 133
	CS7.2: Structured Matrices (PART II)	
Tuesday, 23.08.2011	Chair: 7.2	**Room:**
15:30 - 15:50	**Lars Grasedyck** *Hierarchical Tensor Methods for PDEs with Stochastic Parameters*	p. 134
15:50 - 16:10	**Thomas Mach** *Why the LR Cholesky algorithm does not work for hierarchical matrices*	p. 134

- to be continued -

CS7.2: Structured Matrices (PART II - continuation)

Tuesday, 23.08.2011 Chair: 7.2 **Room:**

16:10 - 16:30	**Nick Vannieuwenhoven** *The sequentially truncated multilinear singular value decomposition for tensor*	p. 135
16:30 - 16:50	**Marko Miladinovic** *Modified SMS method for computing outer inverses of Toeplitz matrices*	p. 135

- end of session -

Isabel Gimenez
Institut de Matematica Multidisciplinar. UP Valencia, Spain

Iterative determination of H-matrices and Irreducible Diagonal Blocks

Monday, 22.08.2011, 15:30 - 15:50, Room to be filled in later by organizers

In the work of Alanelli and Hadjidimos [A new iterative criterion for H-matrices, SIAM J. Matrix Anal. Appl. 428 (2008)] a modification of the algorithm proposed in [Li, Li, Harada, Niki and Tsatsomeros, An iterative criterion for H-matrices, Lin. Alg. Appl. 271 (1998)] is constructed in order to determine irreducible non-singular H-matrices. Simultaneously, a partition of the H-matrices set in three different classes is performed in [Bru, Corral, Gimenez and Mas, Classes of general H-matrices, Lin. Alg. Appl. 429 (2008)] so that the expression "non-singular H-matrix" may not have a clear meaning. Here, we extend the previous algorithm to a general matrix such that the class to which it belongs can be determined. To do that, we show some results on reducible H-matrices and introduce three classes of non-H-matrices. So, the new algorithm determines the (non-)H-matrix character and the corresponding class of a given matrix. Moreover, it can determine the irreducible diagonal blocks of a Frobenius normal form of a reducible matrix. Numerical results for different classes of (non-)H-matrices are included.

This contribution is joint work with Rafael Bru (U Politecnica de Valencia, Spain) and Apostolos Hadjidimos (U of Thessaly, Volos, Greece). (Supported by the Spanish DGI grant MTM2010-18674)

Susana Furtado
CELC-Universidade de Lisboa and Faculdade de Economia do Porto

On the Eigenvalues of Principal Submatrices of J-Normal Matrices

Monday, 22.08.2011, 15:50 - 16:10, Room to be filled in later by organizers

Let M_n be the algebra of $n \times n$ complex matrices and let J be a diagonal involution. Consider the indefinite inner product $[\cdot,\cdot]$ defined by $[x,y] = y^*Jx$, $x, y \in \mathbb{C}^n$. A matrix $A \in M_n$ is said to be J-normal if $A^\# A = AA^\#$, in which $A^\#$ is the J-adjoint of A defined by $[Ax, y] = [x, A^\# y]$ for any $x, y \in \mathbb{C}^n$ (that is, $A^\# = JA^*J$). We say that $U \in M_n$ is a J-unitary matrix if $U^{-1} = U^\#$. A matrix A is J-unitarily diagonalizable if there exists a J-unitary matrix U such that $U^\# AU$ is diagonal.
In this talk we consider the following problem: give necessary and sufficient conditions for the existence of a J-normal matrix A with prescribed eigenvalues for A and some of its $(n-1) \times (n-1)$ principal submatrices. The particular case in which A is J-unitarily diagonalizable is considered. The general 3×3 case is also studied.

This contribution is joint work with Natália Bebiano and João Providência (Universidade de Coimbra).

Georgios Katsouleas
National Technical University of Athens, Greece

Links on Imbedding Conditions for normal matrices

Monday, 22.08.2011, 16:10 - 16:30, Room to be filled in later by organizers

Let the normal matrices A and B of dimension $n \times n$ and $(n-1) \times (n-1)$ respectively. Fan-Pall in [*Ky Fan and G. Pall, Imbedding conditions for Hermitian and normal matrices, Canadian J. Math., 9 (1957), 298-304*] have proved necessary and sufficient conditions such that $B = V^*AV$, with $V^*V = I_{n-1}$, while necessary (but not sufficient) conditions have been presented by other authors in terms of the spectra of A and B, when the dimensions of B are smaller than $n-1$, for example in [*D. Carlson and E. Marques de Sa, Generalized minimax and interlacing theorems, Linear Multilinear Algebra, 15 (1984), 77-103*] and [*J.F. Queiro and A.L. Duarte, Imbedding conditions for normal matrices, Linear Algebra Appl., 430 (2009), 1806-1811*]. An extension of the Fan-Pall theorem for normal matrices with collinear eigenvalues is presented, which is then applied to yield bounds on the number of eigenvalues of A and B inside a closed, convex set, generalizing a recent result in [*R.A. Horn, Problem 42-4, Image, p. 40, issue 43, 2009*]. Moreover, comments and links on several necessary imbedding conditions are stated in this paper.

This contribution is joint work with John Maroulas (NTU Athens, Greece).

Bruno Iannazzo
Dipartimento di Matematica e Informatica, Università di Perugia, Italy

Computing means of structured matrices

Monday, 22.08.2011, 16:30 - 16:50, Room to be filled in later by organizers

Averaging matrices is a problem arising when one has to represent, through a single matrix, the results of several experiments made up by a set of many matrices. Besides the straightforward arithmetic mean, there are other types of means which are suitable for different problems: for positive definite matrices, good averages are obtained by the Karcher mean, which verifies all the properties required from a good definition of geometric mean.
In certain applications there is the need to compute means of positive definite matrices which have further structures. A noticeable example arises in radar signal processing, where the matrices to be averaged are correlation matrices, which are Toeplitz and positive definite. Unfortunately, the Karcher mean of Toeplitz matrices is not Toeplitz. We introduce the new concept of structured geometric mean and prove that it maintains the structure of the input matrices. We restate the properties of geometric mean in terms of the structure and show that most of them are satisfied by our definition. Finally, we provide an iterative algorithm for computing the structured geometric mean and analyze its convergence properties.

This contribution is joint work with Dario Bini (Università di Pisa, Italy).

Lars Grasedyck
IGPM, RWTH Aachen

Hierarchical Tensor Methods for PDEs with Stochastic Parameters

Tuesday, 23.08.2011, 15:30 - 15:50, Room to be filled in later by organizers

We consider the problem to solve a (stochastic) parameter dependent equation

$$A(\omega)u(\omega) = b(\omega), \qquad \omega \in \Omega$$

for systems A governed by partial differential operators that depend on ω. Our aim is to calculate quantities of interest (mean, variance, maximum etc.) of the set of solutions. One way to solve such a problem is by expansion of the system, the right-hand side as well as the solution in independent uncorrelated stochastic variables $\omega_1, \ldots, \omega_p$, and then solve the arising large-scale deterministic problem

$$A(\omega_1, \ldots, \omega_p)u(\omega_1, \ldots, \omega_p) = b(\omega_1, \ldots, \omega_p).$$

An alternative approach is to use (quasi or multilevel) Monte Carlo (MC) methods which require just a simple sampling (M simulations), but these are only useful for certain quantities of interest (e.g. the mean). We will present a new approach based on hierarchical Tucker (HT) representations of tensors. This method is based on standard PDE solvers for deterministic systems. The set of solutions is approximated in a low rank (HT) tensor format that allows for many parameters (thousands).

Thomas Mach
MPI Magdeburg, Germany

Why the LR Cholesky algorithm does not work for hierarchical matrices

Tuesday, 23.08.2011, 15:50 - 16:10, Room to be filled in later by organizers

In 1958 Rutishauser published the LR Cholesky algorithm, which computes the eigenvalues of a symmetric positive definite matrix M_0, by the following iteration:

$$\begin{aligned} L_i L_i^T &:= M_i - \mu I \\ M_{i+1} &:= L_{i+1}^T L_{i+1} + \mu I. \end{aligned}$$

We apply this iteration to symmetric hierarchical matrices, by using the approximate $\mathcal{H}$-Cholesky decomposition and the approximate matrix-matrix multiplication for hierarchical matrices.

We observe, that this algorithm does *not* lead to a structure preserving eigenvalue algorithm, since the local block-wise ranks grow too much. So the algorithm is not of almost quadratic complexity, like we expected first.

This observation will be explained during the talk by applying a theorem on the structure preservation of diagonal-plus-semiseparable matrices under LR Cholesky transformation to the structure of hierarchical matrices. Further we will show that the structure of $\mathcal{H}_\ell$-matrices, a subset of hierarchical matrices, is almost preserved. The LR Cholesky algorithm for $\mathcal{H}_\ell$-matrices is of almost quadratic complexity.

This contribution is joint work with Peter Benner (MPI Magdeburg, Germany).

Nick Vannieuwenhoven
Department of Computer Science, K.U.Leuven

The sequentially truncated multilinear singular value decomposition for tensors

Tuesday, 23.08.2011, 16:10 - 16:30, Room to be filled in later by organizers

In this talk, we present a new algorithm to compute a good low multilinear rank approximation to a tensor. The truncated multilinear singular value decomposition (T-MLSVD) [De Lathauwer *et al.*, a multilinear singular value decomposition, 2000] has been used traditionally for this purpose. Often the computation of the T-MLSVD is a costly and important first step in optimization-based algorithms, such as the higher-order orthogonal iterations (HOOI) [De Lathauwer *et al.*, On the best rank-1 and rank-$(R_1, R_2, \ldots, R_N)$ approximation of higher-order tensors, 2000].
In this talk, we present the sequentially truncated multilinear singular value decomposition (ST-MLSVD). The algorithm improves upon the T-MLSVD in two important respects: it improves the approximation error and significantly decreases the computation time (in some cases proportional to the order of the tensor). We also present a novel expression for the error of any Tucker decomposition with orthogonal factor matrices.

This contribution is joint work with Raf Vandebril (K.U.Leuven, Belgium), and Karl Meerbergen (K.U.Leuven, Belgium).

Marko Miladinovic
Faculty of Sciences and Mathematics, Nis, Serbia

Modified SMS method for computing outer inverses of Toeplitz matrices

Tuesday, 23.08.2011, 16:30 - 16:50, Room to be filled in later by organizers

We introduce a new algorithm based on the successive matrix squaring (SMS) method. This algorithm uses the strategy of ε-displacement rank in order to find various outer inverses with prescribed ranges and null spaces of a square Toeplitz matrix. Using the idea of displacement theory which decreases memory space requirements as well as computational cost, our method found to be very effective for Toeplitz matrices.

This contribution is joint work with Predrag Stanimirovic (Faculty of Sciences and Mathematics, University of Nis, Serbia) and Sladjana Miljkovic (Faculty of Sciences and Mathematics, University of Nis, Serbia).

CS8: Matrix Polynomials and Products

	CS8: Matrix Polynomials and Products	
Friday, 26.08.2011	Chair: 8	**Room:**
15:30 - 15:50	**Prashant Batra**	
	Maximum modulus estimates for generalized eigenvalues of matrix polynomials	p. 137
15:50 - 16:10	**Maria Isabel Bueno Cachadina**	
	Recovery of eigenvectors of matrix polynomials from generalized Fielder linearizations.	p. 137
16:10 - 16:30	**Daniel Kressner**	
	Codimensions and generic canonical forms for generalized matrix products	p. 138
16:30 - 16:50	**Massimo Franchi**	
	Spectral analysis of square matrix polynomials by local rank factorization	p. 138
16:50 - 17:10	**Javier Pérez-Álvaro**	
	Condition numbers of Fiedler Companion matrices	p. 139

- end of session -

Prashant Batra
Technische Universität Hamburg-Harburg (Hamburg University of Technology)

Maximum modulus estimates for generalized eigenvalues of matrix polynomials

Friday, 26.08.2011, 15:30 - 15:50, Room to be filled in later by organizers

For iterative solutions of multi-variable differential equations as well as condition estimates, good approximations of the largest modulus of the generalized eigenvalues of the corresponding matrix polynomial $P \in C^{n\times n}[x]$ are helpful. We review the existing approaches to estimate $\mu := \max\{|\lambda| : \lambda \in C, P(\lambda)$ is singular$\}$ (where the leading matrix coefficient, of P is, by assumption, non-singular). We make some new observations: If the largest root modulus σ of a complex polynomial $p \in C[x]$, where p is constructed from the norms of matrix coefficients, is used to estimate μ, there exists a best choice for p; the value σ with $\sigma \geq \mu$ may be approximated (via a Newton iteration) or estimated. We exhibit a nearly optimal estimator $F = F(p)$ such that $2\sigma \geq F \geq \sigma \geq \mu$. If the upper bounds for μ, i.e. F or σ respectively, are not sufficient, the full matrix polynomial information of P must be used: We suggest a block companion matrix C_R for P which is computable with considerably less effort than the Frobenius block companion matrix. The generalization of the Girard-Newton identities facilitates computable inclusions $0 < l_i \leq \mu \leq U_i$ which allow an *a priori* assessment of any numerical bound ρ with $\rho \geq \mu$. Further, inclusions of μ with constantly limited maximal relative width may be obtained. We illustrate our combined findings by numerical examples.

Maria Isabel Bueno Cachadina
University of California, Santa Barbara

Recovery of eigenvectors of matrix polynomials from generalized Fielder linearizations

Friday, 26.08.2011, 15:50 - 16:10, Room to be filled in later by organizers

The study of linearizations preserving the structure of symmetric and palindromic polynomials has recently awoken a great interest among many researchers in numerical analysis because of the importance of the algorithms that preserve the symmetries imposed by those structures in the spectral information of the polynomial.
A linearization is useful from the numerical point of view if it is possible to recover the eigenvectors of a matrix polynomial from the eigenvectors of the linearization in a simple way. In the literature no recovery methods for structured linearizations based on strict equivalencies of Fiedler pencils can be found. It is well known that this kind of linearizations offer some benefits with respect to other types of linearizations. For example, when the polynomial has odd degree there always exist strong linearizations without imposing additional conditions.
In this talk we present very simple recovery formulas for a broad class of strong linearizations that includes, in particular, all the structured linearizations based on Fiedler pencil equivalencies known to date. The simplicity of the recovery formulas contrast with the non-trivial definition of the pencils in this family of linearizations.

This contribution is joint work with F. De Teran (Universidad Carlos III de Madrid, Spain) and F. M. Dopico (Universidad Carlos III de Madrid, Spain).

Daniel Kressner
ETH Zurich

Codimensions and generic canonical forms for generalized matrix products

Friday, 26.08.2011, 16:10 - 16:30, Room to be filled in later by organizers

A *generalized matrix product* can be formally written as $A_p^{s_p} A_{p-1}^{s_{p-1}} \cdots A_2^{s_2} A_1^{s_1}$, where $s_i \in \{-1, +1\}$ and $(A_1, \ldots, A_p)$ is a tuple of (possibly rectangular) matrices of suitable dimensions. The *periodic eigenvalue problem* related to such a product represents a nontrivial extension of generalized eigenvalue and singular value problems. While the classification of generalized matrix products under eigenvalue-preserving similarity transformations and the corresponding canonical forms have been known since the 1970ies, the question of finding *generic* canonical forms has only recently been addressed in full generality. In this talk, we present such generic forms by computing the codimension of the orbit generated by all similarity transformations of a given generalized matrix product. This can be reduced to computing the so called cointeractions between two different blocks in the canonical form. A number of techniques are applied to keep the number of possibilities for different types of cointeractions limited. Nevertheless, the matter remains highly technical. Possibly more importantely, we present an algorithm and software for extracting the generically regular part of a generalized matrix product.

This contribution is joint work with Bo Kågström and Lars Karlsson (both Umeå University, Sweden).

Massimo Franchi
Università di Roma “La Sapienza”, Italy

Spectral analysis of square matrix polynomials by local rank factorization

Friday, 26.08.2011, 16:30 - 16:50, Room to be filled in later by organizers

A method of contructing the Smith form as well as associated equivalence transformations for square matrix polynomials $A(\lambda)$ is presented; the method employs a finite sequence of ‘local rank factorizations’ and it is shown to provide a complete and explicit description of Jordan pairs. When $A(\lambda) = A - \lambda I$, the analysis delivers the Jordan form of A and a Jordan basis.

This contribution is joint work with Paolo Paruolo (Università dell’Insubria, Italy).

Javier Pérez-Álvaro
Department of Mathematics, Universidad Carlos III de Madrid, Spain

Condition numbers of Fiedler Companion matrices

Friday, 26.08.2011, 16:50 - 17:10, Room to be filled in later by organizers

In 2003 Miroslav Fiedler introduced a new family of companion matrices of a given monic scalar polynomial. This family has been used in different contexts and generalized in several ways, in particular to matrix polynomials. Many interesting algebraic properties of Fiedler companion matrices have been established by groups of researchers from diverse countries. However, as far as we know, it has not been studied if these matrices are better for computational purposes than the classical Frobenius companion form. In this talk, we start this study by considering the traditional condition number of Fiedler companion matrices and its comparison with the condition number of the classical companion form, which is known to be often very large. In particular, we present explicit formulae for the condition number of any Fiedler companion matrix in the 1-norm and the ∞-norm. In addition, we show that pentadiagonal Fiedler companion matrices may be much better conditioned than the classical companion form for many scalar polynomials.

This contribution is joint work with Fernando De Terán (Universidad Carlos III de Madrid, Spain) and Froilán M. Dopico (Universidad Carlos III de Madrid, Spain).

CS9: Stochastics

	CS9: Stochastics	
Monday, 22.08.2011	Chair: 9	**Room:**
15:30 - 15:50	**Alexander Litvinenko**	
	Low-rank response surface in uncertainties quantification framework	p. 141
15:50 - 16:10	**Rainer Niekamp**	
	A Posteriori Adaptive Low-Rank Approximation of Probabilistic Models	p. 141
16:10 - 16:30	**Bojana V. Rosić**	
	Bayesian Identification for non-Gaussian Parameters	p. 142
16:30 - 16:50	**Geir Dahl**	
	Martingale matrix classes	p. 142

- end of session -

Alexander Litvinenko
Institut für Wissenschaftliches Rechnen, TU Braunschweig, Germany

Low-rank response surface in uncertainties quantification framework

Monday, 22.08.2011, 15:30 - 15:50, Room to be filled in later by organizers

Very common numerical methods to quantify uncertainties are Monte Carlo methods and collocation methods. Uncertain parameters are sampled many times (can be hundred tausends) and then for each sample the corresponding deterministic problem is solved. After that, all obtained solutions, which are large vectors, are used for post-processing, e.g. to compute some statistics. We offer a data compression technique which allows us to compress (via QR decomposition) the data (PCE coefficients, realisations of the solution) incoming from MC or collocation methods. This compression is done on the fly with a log-linear complexity and log-linear storage requirement. Then the resulting low-rank decomposition is used for post-processing — computing the mean value and variance of the solution.
As an example we consider problem of quantification of uncertainties in numerical aerodynamic. We compute the low-rank response surfaces for the aerodynamic solutions (pressure, density, velocity fields). This response surfaces are used to compute different statistics needed for researching propagation of uncertainties.

This contribution is joint work with Hermann G. Matthies (TU Braunschweig, Germany).

Rainer Niekamp
Institute of Scientific Computing, TU Braunschweig, Germany

A Posteriori Adaptive Low-Rank Approximation of Probabilistic Models

Monday, 22.08.2011, 15:50 - 16:10, Room to be filled in later by organizers

We consider a physical phenomenon with random heterogeneity in its medium. The corresponding mathematical formulation is described stochastically in this work. A recent but established numerical scheme to approximate the unknown is the Spectral Stochastic Finite Element Method (SSFEM) at which the discretisation inside the weak form is done by Finite Elements for the geometrical space and truncated Polynomial Chaos Expansions (PCEs) for the stochastic space. A classical choice of stochastic basis functions let the SSFEM suffer from the Curse of Dimension. Additionally the coefficient matrix of the solution – summarising the geometrical and stochastic degrees of freedom – becomes rapidly large, when increasing the ansatz.
We introduce techniques going against both of the mentioned difficulties. The solution is represented by a Low-Rank approximation derived from the expectation of the minimum total potential energy principle. The stochastic solution space is constructed adaptively by considering a conditioned form of the residual as an error indicator.

This contribution is joint work with Martin Krosche (TU Braunschweig, Germany).

Bojana V. Rosić
Institut für Wissenschaftliches Rechnen, TU Braunschweig, Germany

Bayesian Identification for non-Gaussian Parameters

Monday, 22.08.2011, 16:10 - 16:30, Room to be filled in later by organizers

Inverse problems and identification procedures are known to lead to ill-posed problems in the sense of Hadamard when considered in a deterministic setting. In a probabilistic Bayesian setting, on the other hand, they are well-posed. In the simplest setting of a linear system and Gaussian randomness this leads to the well-known Kalman Filter (KF) procedures. Extensions to nonlinear or non-Gaussian settings which are based on linearisation like the extended Kalman Filter (EKF) are only of limited applicability. Without linearisation, they invariably involve some kind of sampling, e.g. in the form of ensemble Kalman Filter (EnKF), particle filters, or Markov chain Monte Carlo (MCMC) methods. Here we cast the probabilistic identification problem in a functional approximation setting - the best known of which is the polynomial chaos expansion (PCE) - and the linear Bayes form of updating. In this way the identification process can be carried out completely deterministically. In the case where the original problem was a deterministic identification task it additionally provides a quantification of the remaining uncertainty in a Bayesian setting. But it can also be used as an identification procedure in an originally (frequent) probabilistic setting. We give numerical examples of both.

This contribution is joint work with Tarek El-Moselhy (MIT,USA), Alexander Litvinenko, Oliver Pajonk and Hermann G. Matthies (TU Braunschweig, Germany).

Geir Dahl
University of Oslo, Norway

Martingale matrix classes

Monday, 22.08.2011, 16:30 - 16:50, Room to be filled in later by organizers

Martingale theory plays a central role in modern probability, stochastic analysis and related areas as mathematical finance. Martingales with finite time and probability space may be viewed as matrices satisfying certain conditions. We introduce and investigate several properties of this matrix class, consider related polyhedra and indicate why these objects are of interest from a combinatorial matrix theory point of view.

CS10: Graph Theory

	CS10.1 Graph Theory (PART I)	
Monday, 22.08.2011	Chair: 10.1	**Room:**
17:00 - 17:20	**Miriam Farber**	
	Upper bounds for the Laplacian eigenvalues of weighted and unweighted graphs	p. 145
17:20 - 17:40	**Pavel Chebotarev**	
	Matrices that satisfy the graph bottleneck identity produce geodetic distances	p. 145
17:40 - 18:00	**Sanzheng Qiao**	
	New Algorithms for Computing the Minkowski Reduced Lattice Bases	p. 146
18:00 - 18:20	**Wen Zhang**	
	A Delayed Size-reduction Technique for Speeding Up the LLL Algorithm	p. 146
18:20 - 18:40	**Naomi Shaked-Monderer**	
	Matrices Attaining the Minimum Semidefinite Rank of a Chordal Graph	p. 147
	CS10.2 Graph Theory (PART II)	
Tuesday, 23.08.2011	Chair: 10.2	**Room:**
15:30 - 15:50	**Bit-Shun Tam**	
	Graphs whose adjacency matrices have rank equal to the number of distinct nonzero rows	p. 147
15:50 - 16:10	**Milan Bašić**	
	Which weighted circulant networks have perfect state transfer?	p. 148

- to be continued -

CS10.2 Graph Theory (PART II - continuation)

Tuesday, 23.08.2011	Chair: 10.2	**Room: R3**
16:10 - 16:30	**Felix Goldberg** *Complete classification of optimal Colin de Verdière matrices of the graph $K_{4,4}$*	p. 148
16:30 - 16:50	**Thomas Ernst** *The Ward q-addition, a universal tool for q-calculus within linear algebra*	p. 149

- end of session -

Miriam Farber
Technion - Israel Institute of Technology

Upper bounds for the Laplacian eigenvalues of weighted and unweighted graphs

Monday, 22.08.2011, 17:00 - 17:20, Room to be filled in later by organizers

In this paper we give a new upper bound for the Laplacian eigenvalues of an unweighted graph in terms of its vertex degrees and give examples in which the bound is tight. We also introduce upper and lower bounds for the Laplacian eigenvalues of weighted graphs, and compare these with the special case of unweighted graphs.

Pavel Chebotarev
Institute of Control Sciences of the Russian Academy of Sciences

Matrices that satisfy the graph bottleneck identity produce geodetic distances

Monday, 22.08.2011, 17:20 - 17:40, Room to be filled in later by organizers

A matrix $S = (s_{ij}) \in \mathbb{R}^{n\times n}$ is said to determine a *transitional measure* for a digraph Γ on n vertices if for all $i, j, k \in \{1, \ldots, n\}$, the *transition inequality* $s_{ij}\, s_{jk} \le s_{ik}\, s_{jj}$ holds and reduces to the equality (called the *graph bottleneck identity*) if and only if every path in Γ from i to k contains j. We show that every positive transitional measure produces a distance by means of the elementwise logarithmic transformation $H = \overrightarrow{\ln S}$ and the inverse covariance mapping $D = \frac{1}{2}(h\mathbf{1}^{\mathrm{T}} + \mathbf{1}h^{\mathrm{T}} - H - H^{\mathrm{T}})$, so that $d_{ij} = \frac{1}{2}\ln(s_{ii}\, s_{jj}/s_{ij}\, s_{ji}),\ i, j = 1, \ldots, n$, where h is the column vector containing the diagonal entries of H, $\mathbf{1}$ is the column of n ones, and A^{T} is the transpose of A. Moreover, the resulting distance $d(\cdot,\cdot)$ is *graph-geodetic*, that is, $d(i, j) + d(j, k) = d(i, k)$ holds if and only if every path in Γ connecting i and k contains j. Five types of matrices that determine transitional measures for a digraph are presented, namely, the matrices of adjusted path weights, connection reliabilities, route weights (provided that they are finite), and the weights of in-forests and out-forests. The results have "undirected" counterparts. The present approach enables one to fill the gap between the shortest path distance and the resistance distance for undirected graphs by constructing a parametric class of *logarithmic forest distances*. The construction of the class is based on the matrix forest theorem and the transition inequality.

Sanzheng Qiao
McMaster University, Canada

New Algorithms for Computing the Minkowski Reduced Lattice Bases

Monday, 22.08.2011, 17:40 - 18:00, Room to be filled in later by organizers

Lattice basis reduction is of fundamental importance in lattice theory and many other fields in mathematics. There are various definitions of a reduced basis, of which the Minkowski reduced basis is the most important one. The computation of the Minkowski reduced bases consists of a sequence of constrained integer least squares problems. All known algorithms for solving such problem are based on the Kannan strategy or the Phost strategy, whose running time quickly becomes prohibitive as the dimension of lattice increases.
In this talk, we present two new algorithms for constructing a Minkowski reduced basis for any real lattice. Both algorithms are based on the Schnorr-Euchner strategy, which is much more efficient than both the Kannan strategy and the Phost strategy. To improve the performance, the LLL algorithm can be used as a preprocessor for our first algorithm. For the second algorithm, we propose a variant of the LLL algorithm, called incomplete LLL algorithm, as a preprocessor. Our numerical experiments demonstrate that our algorithms significantly outperform the existing algorithms.

This contribution is joint work with Wen Zhang and Yimin Wei (Fudan University, P.R. China).

Wen Zhang
Fudan University, P.R. China

A Delayed Size-reduction Technique for Speeding Up the LLL Algorithm

Monday, 22.08.2011, 18:00 - 18:20, Room to be filled in later by organizers

The LLL algorithm authored by Lenstra, Lenstra, and Lovász is a lattice basis reduction method. The problem of reducing a lattice basis has wide applications. In time critical applications, such as wireless communications, the speed of the LLL algorithm is crucial. In this paper, we propose a technique, called delayed size-reduction, to speed up the LLL algorithm. Our algorithm can significantly speed up the LLL algorithm. For example, for problems of size 80, our algorithm can be twice as fast as the original LLL algorithm. For larger size problems, the speed-up is greater. The speed-up is achieved by delaying some operations and consolidating procedures, consequently, reducing the number of conditional instructions and eliminating redundant operations. Our analysis shows that the complexity of our algorithm for an integer lattice basis matrix A of size n is $O(n^3 \log \|A\|)$. In contrast, the complexity of the original LLL algorithm for an integer lattice basis matrix A is known to be $O(n^4 \log \|A\|)$. We also present the first complexity analysis of the LLL-like algorithms for real lattice basis and show that the complexity of our algorithm is $O(n^3 \log(\mathrm{cond}(A)))$.

This contribution is joint work with Sanzheng Qiao (McMaster University, Canada) and Yimin Wei (Fudan University, P.R. China).

Naomi Shaked-Monderer
Emek Yezreel College, Emek Yezreel 19300, Israel

Matrices Attaining the Minimum Semidefinite Rank of a Chordal Graph

Monday, 22.08.2011, 18:20 - 18:40, Room to be filled in later by organizers

Every positive semidefinite matrix whose graph G is chordal, may be represented as a sum of rank 1 positive semidefinite matrices whose graphs are subgraphs of G. We show that if the matrix is of minimum semidefinite rank, then there is a unique such representation. This result is used to give a full characterization of the completely positive matrices of minimum rank with a given chordal graph.
A matrix A is *completely positive* if it can be factored as $A = BB^T$, where B is nonnegative, not necessarily square. The minimal number of columns in such B is the *cp-rank* of A. In general, determining whether a given matrix A is completely positive, computing its cp-rank, and finding a factorization $A = BB^T$, where the number of columns of B is $\text{cp-rank}\, A$, are all very hard problems. We show that in the case that the graph of A is chordal and A is of minimum rank, these problems have simple answers: In this case, A has a unique, easily computable, factorization in the above form, and its cp-rank is equal to its rank.
We also characterize all chordal graphs with the property that every minimum rank doubly nonnegative matrix realization of the graph is completely positive.

Bit-Shun Tam
Tamkang University, New Taipei City, Taiwan

Graphs whose adjacency matrices have rank equal to the number of distinct nonzero rows

Tuesday, 23.08.2011, 15:30 - 15:50, Room to be filled in later by organizers

It is proved that for any graph, the rank of the adjacency matrix is equal to the number of distinct nonzero rows of the adjacency matrix if and only if the reduced adjacency matrix of the graph is nonsingular. Based on the latter result, an alternative proof is provided for the known fact that every cograph satisfies the said rank property. It is also conjectured that for any graph G that satisfies the said rank property, we have $z(G)^T B(G)^{-1} e^{(t)} > 1$, where $B(G)$ is the reduced adjacency matrix of $G, e^{(t)}$ is the vector of all 1's in R^t, t being the number of neighborhood equivalence classes of G, and $z(G)$ is the vector in R^t whose components are the cardinalities of the neighborhood equivalence classes of G.

This talk is based on a joint work with Shu-Hui Wu (Taipei College of Maritime Technology, Taipei, Taiwan 111).

Milan Bašić
Faculty of Sciences and Mathematics, University of Niš, Serbia

Which weighted circulant networks have perfect state transfer?

Tuesday, 23.08.2011, 15:50 - 16:10, Room to be filled in later by organizers

The question of perfect state transfer existence in quantum spin networks based on weighted graphs has been recently presented by many authors. We give a simple condition for characterizing weighted circulant graphs allowing perfect state transfer in terms of their eigenvalues. This is done by extending the results about quantum periodicity existence in the networks given in [N. Saxena, S. Severini, I. Shparlinski, *Parameters of integral circulant graphs and periodic quantum dynamics*, International Journal of Quantum Information 5 (2007), 417–430.] and characterizing integral graphs among weighted circulant graphs. Finally, classes of weighted circulant graphs supporting perfect state transfer are found. These classes completely cover the class of circulant graphs having perfect state transfer in the unweighted case. In fact, we show that there exists an weighted integral circulant graph with n vertices having perfect state transfer if and only if n is even. Moreover we prove the non-existence of perfect state transfer for several other classes of weighted integral circulant graphs of even order.

Felix Goldberg
Technion-IIT, ISRAEL

Complete classification of optimal Colin de Verdière matrices of the graph $K_{4,4}$

Tuesday, 23.08.2011, 16:10 - 16:30, Room to be filled in later by organizers

In 1990 Colin de Verdière introduced a new spectral invariant of graphs, which has turned out to offer surprising insights into their geometrical structure. Quite possibly, another of its attractions might be that it is often maddeningly difficult to compute.
Furthermore, even if the Colin de Verdière number is known for a given graph, to find an optimal matrix at which it is attained is a highly non-trivial problem as well.
In this talk we shall present a new classification of all the optimal Colin de Verdière matrices of the graph $K_{4,4}$, whose Colin de Verdière number is known to be 5.
The classification is obtained by using some powerful and elegant tools of matrix theory: the Carlson-Haynsworth-Markham theorem on the inertias of generalized Schur complements, results of Marsaglia and Styan on ranks of matrix sums, and Meyer's extension to generalized inverses of the classical Sherman-Morrison-Woodbury formula.

Thomas Ernst
Department of Mathematics, P.O. Box 480, SE-751 06 Uppsala, Sweden

The Ward q-addition, a universal tool for q-calculus within linear algebra

Tuesday, 23.08.2011, 16:30 - 16:50, Room to be filled in later by organizers

We present a universal method to treat q-calculus problems in graph theory, combinatorics and matrix theory. The three subjects are more or less equivalent, but we will concentrate on the last one. To this aim, we will use three new q-deformed matrix multiplications. The first is of general nature. The second, denoted $\cdot_\epsilon$, enables q-analogues of factorisations in connection with the q-deformed Leibniz functional matrix from Yang 2009. The third, denoted $\cdot_q$, is connected to the inversion of the base $\tau : q \to \frac{1}{q}$. The Ward q-addition of two ore more so-called letters in an infinite alphabet in the spirit of Rota, has applications in terms of q-Schur polynomials and a q-analogue of the Young submodule.
By the q-exponential function we can construct q-Pascal matrices and q-analogues of certain Lie groups. This brings us to the q-determinants and the q-orthogonal matrices. The Bernoulli and Stirling numbers are of fundamental importance for combinatorics. By our method we can construct q-Bernoulli and q-Stirling matrices and find q-matrix analogues of the complementary argument theorems for Bernoulli and Euler polynomials.).

CS11: Spectral Analysis and Sensitivity

	CS11: Spectral Analysis and Sensitivity	
Friday, 26.08.2011	Chair: 11	**Room:**
15:30 - 15:50	**Carla Ferreira**	
	Sensitivity of eigenvalues of an unsymmetric tridiagonal matrix	p. 151
15:50 - 16:10	**Michael Karow**	
	A Perturbation Bound for Invariant Subspaces	p. 151
16:10 - 16:30	**Yuji Nakatsukasa**	
	A Gerschgorin-type eigenvalue inclusion set for generalized eigenvalue problems	p. 152
16:30 - 16:50	**Sonia Tarragona**	
	Perturbation analysis of simple eigenvalues and eigenvectors of singular linear systems	p. 152
16:50 - 17:10	**Christian Mehl**	
	Generic rank one perturbation of complex Hamiltonian matrices	p. 153

- end of session -

Carla Ferreira
Mathematics and Applications Department, University of Minho, Portugal

Sensitivity of eigenvalues of an unsymmetric tridiagonal matrix

Friday, 26.08.2011, 15:30 - 15:50, Room to be filled in later by organizers

The Wilkinson condition number ignores the tridiagonal form and so can be excessively pessimistic. We present several *relative* condition numbers that exploit the tridiagonal form. Some of these numbers are derived from different factored forms (or representations) of the matrix and so they shed light on which factored forms are best for computation. We show some interesting examples and report that surprisingly many tridiagonals define all their eigenvalues to good relative accuracy.

This contribution is joint work with Beresford Parlett (University of California, Berkeley).

Michael Karow
Technische Universität Berlin, Germany

A Perturbation Bound for Invariant Subspaces

Friday, 26.08.2011, 15:50 - 16:10, Room to be filled in later by organizers

Let X be a simple invariant subspace of the square matrix A. If the matrix E is sufficiently small then the matrix $A + E$ has a simple invariant subspace X_E which is close to X. We provide a new bound for the maximum canonical angle between X and X_E. Furthermore, we compare our estimate with the classical results by Davis and Kahan, Demmel and Stewart.

Yuji Nakatsukasa
University of Manchester, UK

A Gerschgorin-type eigenvalue inclusion set for generalized eigenvalue problems

Friday, 26.08.2011, 16:10 - 16:30, Room to be filled in later by organizers

Gerschgorin's theorem defines in the complex plane a union of n disks that contains all the n eigenvalues of any square matrix. It is an extremely simple yet useful tool for obtaining eigenvalue bounds. For the generalized eigenvalue problem $Ax = \lambda Bx$, [Stewart, *Math. Comp.* '75] derives a Gerschgorin-type eigenvalue inclusion set, but it is defined in the Chordal metric, which makes its application less intuitive. A more recent result [Kostic, Cvetkovic, Varga, *NLAA* '09] uses the standard Euclidean metric, but the bound is generally defined by a complicated region.
In this talk I will introduce a new eigenvalue inclusion set for $Ax = \lambda Bx$, defined by circles in the Euclidean metric complex plane. When B is strictly diagonally dominant the set is a union of n disks $\bigcup_{i=1}^{n} \Gamma_i(A, B)$, where

$$\Gamma_i(A,B) \equiv \left\{ z : \left| z - \frac{A_{i,i}}{B_{i,i}} \right| \le \frac{|A_{i,i}| \frac{\sum_{j \neq i} |B_{i,j}|}{|B_{i,i}|} + \sum_{j \neq i} |A_{i,j}|}{|B_{i,i}| - \sum_{j \neq i} |B_{i,j}|} \right\} \quad (i = 1, 2, \cdots, n).$$

Similarly to the standard Gerschgorin theorem, computing the new set is inexpensive, requiring only the diagonal elements and the sum of the absolute values of the off-diagonal elements.

Sonia Tarragona
Universidad de León, León, Spain

Perturbation analysis of simple eigenvalues and eigenvectors of singular linear systems

Friday, 26.08.2011, 16:30 - 16:50, Room to be filled in later by organizers

Let $E(p)\dot{x} = A(p)x + B(p)u$ be a family of singular linear systems smoothly dependent on a vector of real parameters $p = (p_1, \ldots, p_n)$. In this work we construct versal deformations of the given differentiable family under an equivalence relation, providing a special parametrization of space of systems, which can be effectively applied to perturbation analysis. Furthermore in particular, we study of behavior of a simple eigenvalue of a singular linear system family $E(p)\dot{x} = A(p)x + B(p)u$.

This contribution is joint work with M$^{\text{a}}$ Isabel García-Planas (UPC Barcelona, Spain).

Christian Mehl
Technische Universität Berlin, Germany

Generic rank one perturbation of complex Hamiltonian matrices

Friday, 26.08.2011, 16:50 - 17:10, Room to be filled in later by organizers

We study the perturbation theory of complex Hamiltonian matrices under generic rank one perturbations. If an unstructured perturbation is applied and if the Jordan canonical forms of the original and the perturbed matrix are compared, then generically only (one of) the largest Jordan blocks for a given eigenvalue has disappeared, but all other Jordan blocks for that particular eigenvalue remain the same. The situation is different if one considers structured perturbations. There exist Hamiltonian matrices for which Hamiltonian rank one perturbations will generically increase the size of the largest Jordan block associated with the eigenvalue zero. In the talk, we explain the reasons for this surprising behaviour.

This contribution is joint work with Volker Mehrmann (TU Berlin, Germany), André C.M. Ran (VU Amsterdam, The Netherlands), and Leiba Rodman (College of William and Mary, USA).

CS12: Nonnegative Matrices

	CS12: Nonnegative Matrices	
Tuesday, 23.08.2011	Chair: 12	**Room:**
15:30 - 15:50	**Aikaterini Aretaki**	
	The higher rank numerical range of nonnegative matrices	p. 155
15:50 - 16:10	**Andrey Voynov**	
	Strictly positive products of nonnegative matrices	p. 155
16:10 - 16:30	**Aljosa Peperko**	
	On the functional inequality for the spectral radius of compact operators	p. 156
16:30 - 16:50	**Vladimir Yu. Protasov**	
	Invariant functionals for the Lyapunov exponents of matrices	p. 156

- end of session -

Aikaterini Aretaki
National Technical University of Athens, Greece

The higher rank numerical range of nonnegative matrices

Tuesday, 23.08.2011, 15:30 - 15:50, Room to be filled in later by organizers

Let $k \geq 1$ be a positive integer and $L(\lambda)$ be an $n \times n$ matrix polynomial with coefficients in $\mathrm{C}^{n\times n}$. The k*-rank numerical range* $\Lambda_k(L(\lambda))$ of $L(\lambda)$ is defined by

$$\Lambda_k(L(\lambda)) = \{\lambda : PL(\lambda)P = 0_n \text{ for some } k - \text{rank orthogonal projection } P\}$$

[A. Aretaki-J. Maroulas, 10th WONRA, Krakow, Poland, 2010]. For $k = 1$, $\Lambda_1(L(\lambda))$ is the classical numerical range of a matrix polynomial. Defining the *maximal elements* in $\Lambda_k(L(\lambda))$ to be the set $\{\lambda \in \Lambda_k(L(\lambda)) : |\lambda| = r_k(L)\}$, where $r_k(L) = \max\{|\lambda| : \lambda \in \Lambda_k(L(\lambda))\}$ is the k*-rank numerical radius*, we investigate $\Lambda_k(I\lambda - A)$, when A is an irreducible and entrywise nonnegative matrix. For $k > 1$, it is observed that $r_k(I\lambda - A)$ is not always contained in $\Lambda_k(I\lambda - A)$ as a characteristic example reveals, contrary to the case $k = 1$. Our research also elaborates the number of maximal elements in $\Lambda_k(I\lambda - A)$ and their location on the complex plane, when A is nonnegative with irreducible hermitian part, extending the results in [J. Maroulas-P. Psarrakos-M. Tsatsomeros, Perron-Frobenius Type Results on the Numerical Range, LAA, 49-62, 2002]. Further, considering a Perron matrix polynomial $L(\lambda)$, we apply our results to the set $\Lambda_k(L(\lambda))$ via the companion matrix C_L of $L(\lambda)$.
This is a joint work with John Maroulas (NTU of Athens, Greece).

Andrey Voynov
Moscow State University

Strictly positive products of nonnegative matrices

Tuesday, 23.08.2011, 15:50 - 16:10, Room to be filled in later by organizers

Let $\mathcal{A} = \{A_1, \ldots, A_k\}$ be a finite family of nonnegative $(d \times d)$-matrices; $< \mathcal{A} >$ be the multiplicative semigroup generates by $\mathcal{A}$. We consider the following problem: under which conditions on $\mathcal{A}$ the semigroup $< \mathcal{A} >$ contains at least one positive matrix ? This problem arises naturally in many applications: in the study of the Lyapunov exponents, in nonhomogeneous Markov chains, etc. We present a complete criterion for the existence of a positive matrix in a semigroup and a polynomial algorithm to check it. Clearly, if a positive matrix exists, then the family $\mathcal{A}$ must be *irreducible*, i.e., the matrices $A_1, \ldots, A_k$ have no common invariant subspace among the coordinate planes. The main result is:
Theorem 1. *Suppose that the family $\mathcal{A}$ is irreducible and its matrices have neither zero columns or zero rows; then the semigroup $< \mathcal{A} >$ does not contain a positive matrix if there is a partition of the set of basis vectors $\{e_1, \ldots, e_d\}$ into disjoint nonempty sets $\Omega_1, \ldots, \Omega_n$, $n \geq 2$, such that each matrix A_i acts as a permutation of these sets.* This means that for every operator $A \in \mathcal{A}$ there is a permutation σ of the set $\{1, \ldots, n\}$ such that for every basis vector $e_m \in \Omega_j$ the image $A_i e_m$ belongs to the linear span of $\Omega_{\sigma(j)}$. Theorem 1 generalizes a result of well-known Romanovsky theorem to arbitrary family of matrices.

This contribution is joint work with V. Yu. Protasov (Moscow State University).

Aljosa Peperko
University of Ljubljana, Slovenia

On the functional inequality for the spectral radius of compact operators

Tuesday, 23.08.2011, 16:10 - 16:30, Room to be filled in later by organizers

Elsner et. al. [L. Elsner, D. Hershkowitz and A. Pinkus, Functional inequalities for spectral radii of nonnegative matrices, Linear Algebra Appl. 129, pp. 103–130, 1990] characterized functions $F : \mathbb{R}_+^n \to \mathbb{R}_+$ satisfying

$$r(F(A_1, \ldots, A_n)) \leq F(r(A_1), \ldots, r(A_n))$$

for all non-negative matrices A_1, ..., A_n of the same order, where r denotes the spectral radius. We generalize this result to the setting of infinite non-negative matrices that define compact operators on a Banach sequence space. The work will appear in [A. Peperko, On the functional inequality for the spectral radius of compact operators, to appear in Lin. Multilin. Alg.].

Vladimir Yu. Protasov
Moscow State University, Russia

Invariant functionals for the Lyapunov exponents of matrices

Tuesday, 23.08.2011, 16:30 - 16:50, Room to be filled in later by organizers

The Lyapunov exponents (the exponents of growth for norms of random matrix products) are intensively studied in the literature due to many applications. We introduce a new approach to analyze the Lyapunov exponents based on the notion of invariant positive concave functionals ("antinorms") .
We prove that every family of nonnegative $(d \times d)$–matrices has a continuous monotone concave invariant functional on $\mathbf{R}_+^d$. Under some standard assumptions on the matrices, this functional is strictly positive, i.e., is an antinorm, and the corresponding coefficient equals to the largest Lyapunov exponent. As a corollary we obtain asymptotically sharp estimates for the expected value of the logarithm of norms of matrix products and of their spectral radii. Another corollary is new upper and lower bounds for the Lyapunov exponents of nonnegative matrices. We consider possible extensions of our results to general nonnegative matrix families and present several applications and examples from the theory of difference equations, linear switched systems, etc.

CS13: Control

	CS13.1: Control (PART I)	
Monday, 22.08.2011	Chair: 13.1	**Room:**
15:30 - 15:50	**Kim Hana**	
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15:50 - 16:10	**Alexander Paprotny**	
	Algebraic Multigrid Methods for Discrete Stochastic Optimal Control	p. 159
16:10 - 16:30	**André Ran**	
	Controllability concepts for coordinated linear systems	p. 160
16:30 - 16:50	**Alicia Roca**	
	On the pole placement problem for singular systems	p. 160
	CS13.2: Control (PART II)	
Tuesday, 23.08.2011	Chair: 13.2	**Room:**
17:00 - 17:20	**Christian Schröder**	
	Enforcing Dissipativity of LTI Systems through Structured Eigenvalue Theory	p. 161
17:20 - 17:40	**Chern-Shuh Wang**	
	Sensitivity and Robustness of the State Feedback pole Assignment Problem	p. 161
17:40 - 18:00	**M^{a} Isabel García-Planas**	
	Solving Disturbance Decoupling For Singular Systems By P-D-Feedback And P-D-Output Injection	p. 162

- to be continued -

	CS13.2: Control (PART II - continuation)	
Tuesday, 23.08.2011	Chair: 13.2	**Room:**
18:00 - 18:20	**M. Montserrat López-Cabeceira** *Right coprime factorization of rational matrices over commutative rings*	p. 162
18:20 - 18:40	**Matthias Voigt** *On Negative Imaginary Descriptor Systems*	p. 163

	CS13.3: Control (PART III)	
Thursday, 25.08.2011	Chair: 13.3	**Room:**
17:40 - 18:00	**Jan Homeyer** *A Geometric Point of View on Gyroscopic Stabilization*	p. 163
18:00 - 18:20	**Volker Mehrmann** *Self-adjoint differential-algebraic operators and their use in optimal control*	p. 164
18:20 - 18:40	**Rafael Bru** *On applications of the Brauer theorem*	p. 164

- end of session -

Kim Hana
Department of Mathematics, Sungkyunkwan University, Suwon 440-746, Republic of Korea

Algebraic properties of the companion matrices arising in a control system

Monday, 22.08.2011, 15:30 - 15:50, Room to be filled in later by organizers

We consider the system of first-order differential equations

$$x_j'(t) = x_{j-1}(t) + k_{j-1}x_n(t) + b_{j-1}u(t), \quad x_0 = 0, \ (1 \le j \le n)$$

which arises in modern control theory. In matrix form we have $\mathbf{x}' = C_q\mathbf{x} + \mathbf{b}u(t)$ where $\mathbf{x} = [x_1(t), \ldots, x_n(t)]^T$, $\mathbf{b} = [b_0, \ldots, b_{n-1}]^T$ and C_q is the companion matrix of a polynomial $q(x) = x^n - k_{n-1}x^{n-1} - \ldots - k_1x - k_0$. It can be shown that

$$\mathbf{x}^{(n)} - C_q^n\mathbf{x} = (\mathbf{b}; C_q)[u^{(n-1)}(t), \ldots, u'(t), u(t)]^T$$

where $(\mathbf{b}; C_q) := [\mathbf{b}, C_q\mathbf{b}, \ldots, C_q^{n-1}\mathbf{b}]$ is an $n \times n$ matrix called the controllability matrix. We determine whether the above control system is controllable by examining algebraic properties of the controllability matrix. In addition, an algebraic structure of controllability matrices which leads to a construction of finite matrix fields of order p^n, and related eigenvalue problems are observed.

This contribution is joint work with Gi-Sang Cheon (Department of Mathematics, Sungkyunkwan University, Republic of Korea).

Alexander Paprotny
Technische Universität Berlin, Germany

Algebraic Multigrid Methods for Discrete Stochastic Optimal Control

Monday, 22.08.2011, 15:50 - 16:10, Room to be filled in later by organizers

We study the convergence behavior of aggregation-based algebraic multigrid methods applied to *unsymmetric* systems of the form $(I - \gamma P)v = b$, where P is row-stochastic, $0 \le \gamma < 1$, and I denotes the identity matrix. Specifically, we provide bounds on the convergence rate of the considered methods under the assumption that P be close to block diagonal. This assumption is justified by the underlying application to discrete stochastic optimal control problems arising in the context of recommendation sytems for online shops.
Furthermore, we consider generalizations to systems of the form $(I - Q)v = b$, where Q is row-substochastic, and present a convergence result for a generalization of algebraic multigrid to a stochastic iterative setting.
The contribution is based on the author's diploma thesis, which is located at *http://www.math.tu-berlin.de/˜paprotny/Files/thesis.pdf*.

This contribution is joint work with Jochen Garcke (Technische Universität Berlin, Germany), Prashant Batra (Technische Universität Hamburg-Harburg, Germany), and Michael Thess (prudsys AG, Germany).

André Ran
VU University Amsterdam

Controllability concepts for coordinated linear systems

Monday, 22.08.2011, 16:10 - 16:30, Room to be filled in later by organizers

In this talk we shall discuss coordinated linear systems, and several controllability concepts related to them. A coordinated system is a special type of distributed system which consists of a coordinator and several subsystems which are coordinated by it. Communication within a coordinated system is (mostly) restricted to communication from the coordinator to the subsystems.
Coordinated linear systems have state-space realizations in which the matrices reflect the special system structure.
The usual concept of controllability might not be very suitable for the special case of a coordinated linear system. To be specific, the traditional concept of controllability does not take into account which part of the state of the full system is controlled by action of the coordinator and which part is controlled by action of the subsystems. In the talk we shall present several concepts of controllabilty which are more suitable for coordinated linear systems, give and formulate a controllability decomposition of the system.

This contribution is based on joint work with P.L. Kempker (VU and CWI, Amsterdam) and J.H. van Schuppen (CWI Amsterdam and Delft University of Technology).

Alicia Roca
Universidad Politécnica de Valencia, Spain

On the pole placement problem for singular systems

Monday, 22.08.2011, 16:30 - 16:50, Room to be filled in later by organizers

Given a singular system with outputs

$$\begin{aligned} E\dot{x} &= Ax + Bu, \\ y &= Cx, \end{aligned}$$

$E, A \in F^{h\times n}, B \in F^{h\times m}, C \in F^{p\times n}$, and a monic homogeneous polynomial $f \in F[x, y]$, we obtain necessary and sufficient conditions for the existence of a state feedback matrix F and an output injection K such that the state matrix $sE - (A + BF + KC)$ has f as characteristic polynomial, under a regularizability condition on the system.

Christian Schröder
TU Berlin, Germany

Enforcing Dissipativity of LTI Systems through Structured Eigenvalue Theory

Tuesday, 23.08.2011, 17:00 - 17:20, Room to be filled in later by organizers

Consider the linear time-invariant dynamical system

$$E\dot{x}(t) = Ax(t) + B(u(t), \quad y(t) = Cx(t) + Du(t).$$

We assume that (E, A, B, C, D) is close to a dissipative system, i.e., colloquially speaking, it (almost) cannot output more energy than was fed to it.
Under mild assumptions a sufficient condition for dissipativity is that the symmetric/skew-symmetric pencil

$$\lambda \begin{bmatrix} 0 & E & 0 \\ -E^T & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} - \begin{bmatrix} 0 & A & B \\ A^T & 0 & C \\ B^T & C & D + D^T \end{bmatrix}$$

has no purely imaginary eigenvalues.
Using structured eigenvalue perturbation results we will construct a perturbation to the pencil that moves all eigenvalues from the imaginary axis resulting in a perturbed system $(\tilde{E}, \tilde{A}, \tilde{B}, \tilde{C}, \tilde{D})$ that is guaranteed to be dissipative.

This contribution is joint work with Tobias Brüll (TU Berlin, Germany).

Chern-Shuh Wang
Department of Mathematics, National Cheng Kung University, Tainan, 701, Taiwan

Sensitivity and Robustness of the State Feedback pole Assignment Problem

Tuesday, 23.08.2011, 17:20 - 17:40, Room to be filled in later by organizers

In literatures, for instance, [Sun (SIMAX1996), Mehrmann/Xu (ETNA1996), Mehrmann/Xu (ETNA1997)], condition numbers and perturbation bounds were produced for the state feedback pole assignment problem (SFPAP), for the single- and multi-input cases with simple closed-loop eigenvalues. In this talk, we consider the same problem in a different approach with weaker assumptions, producing simpler condition numbers and perturbation results. In view of the robustness for the problem, the bounds of condition numbers can be reduced. This evidences that the SFPAP is not to be intrinsically ill-conditioned. Numerical results illustate the relation between the robustness and the sensitivity of SFPAP.
This contribution is joint work with Eric K. Chu (Monash Univ., Australia), Ching-Chang Yen (NKCU, Taiwan) and Chang-Yi Weng (Monash Univ., Australia).

M^{a} Isabel García-Planas
Universitat Politècnica de Catalunya, Barcelona, Spain

Solving Disturbance Decoupling For Singular Systems By P-D-Feedback And P-D-Output Injection

Tuesday, 23.08.2011, 17:40 - 18:00, Room to be filled in later by organizers

In this work we analyze the problem of constructing feedbacks and/or output injections that suppress this disturbance in the sense that it does not affect the input-output behavior of the system and makes the resulting closed-loop system regular and of index at most one. All results are based on a complete system of invariants defining a canonical reduced form. The collection of invariants can be easily obtained computing ranks of certain matrices.

M. Montserrat López-Cabeceira
Universidad de León, León, Spain

Right coprime factorization of rational matrices over commutative rings

Tuesday, 23.08.2011, 18:00 - 18:20, Room to be filled in later by organizers

Let R be a commutative ring with unit element and let $H(s)$ be a rational matrix representing the singular linear dynamical system $\Sigma = (E, A, B, C)$ over R. In this paper we analyze singular systems (E, A, B, C) for which there exist feedbacks and output injections, such that the transfer matrix of the close-loop system obtained is polynomial. This task links up with right coprime factorization of $H(s)$. With a view to design a procedure obtaining such coprime factorization of transfer matrix, we focus this problem over fields and principal ideals domains. This contribution is joint work with M^{a} Isabel García-Planas (UPC Barcelona, Spain).

Matthias Voigt
Max Planck Institute for Dynamics of Complex Technical Systems Magdeburg

On Negative Imaginary Descriptor Systems

Tuesday, 23.08.2011, 18:20 - 18:40, Time, Room to be filled in later by organizers

Negative imaginary descriptor systems arise, e.g., during the modeling of holonomically constrained flexible structures with colocated force actuation and position measurement or during the modeling of certain electrical circuits. In this talk we provide some theory for this kind of systems. We derive a skew-Hamiltonian/Hamiltonian matrix pencil that can be used to check the negative imaginary property of the system via the existence of simple, finite, purely imaginary eigenvalues. Similarly to the positive real case, we can enforce negative imaginarity by suitable perturbations of this skew-Hamiltonian/Hamiltonian matrix pencil.
This is a joint work with Peter Benner (MPI Magdeburg).

Jan Homeyer
TU Kaiserslautern, Germany

A Geometric Point of View on Gyroscopic Stabilization

Thursday, 25.08.2011, 17:40 - 18:00, Room to be filled in later by organizers

We consider the unstable system $\ddot{x}+D\dot{x}+Kx=0$ with positive definite stiffness matrix K and indefinite damping matrix D. The question was raised by Arnold and Maunder (1961) whether this system can be stabilized by adding a gyroscopic term $G\dot{x}$ with a suitable skew-symmetric matrix $G=-G^T$. We call G a gyroscopic stabilizer if the system $\ddot{x}+(D+G)\dot{x}+Kx=0$ is stable. Necessary for the existence of G are the conditions trace $D>0$ and trace $K^{-1}D>0$, see Müller (1971).
In our talk, the problem of constructing a suitable G is reformulated as an inverse eigenvector problem similar to the approach by Kliem and Müller (1997) and G is constructed via identifying certain subspaces of $\mathbb{R}^n$ such that the restriction of the trace of D on these subspaces is positive. These subspaces then serve as eigenspaces for conjugate pairs of eigenvalues of G.
For space dimensions $n=3,4$, we show the existence of a stabilizing G. The conditions posed on the eigenspaces of G are interpreted geometrically and thereby, we quantify the set of matrices G that serve as gyroscopic stabilizers.

This contribution is joint work with Tobias Damm (TU Kaiserslautern, Germany).

Volker Mehrmann
Inst. f. Mathematik, TU Berlin

Self-adjoint differential-algebraic operators and their use in optimal control

Thursday, 25.08.2011, 18:00 - 18:20, Room to be filled in later by organizers

We discuss self-adjoint differential-algebraic operators that arise in the numerical solution of linear quadratic optimal control problems for linear descriptor systems with variable coefficients. These operators generalize even matrix pencils as they arise in the constant coefficient case. We analyze the properties of these operators and prove a normal form under congruence. We also show how this form can be used in the numerical solution of the control problem.

This contribution is joint work with Peter Kunkel (Univ. Leipzig, Germany) and Lena Scholz (TU Berlin, Germany).

Rafael Bru
Institut de Matemàtica Multidisciplinar. Univ. Politècnica de València. Spain.

On applications of the Brauer theorem

Thursday, 25.08.2011, 18:20 - 18:40, Room to be filled in later by organizers

Given a square matrix A the Brauer's theorem [Limits for the characteristic roots of matrices IV: Applications to stochastic matrices, Duke Math. J. 19 (1952), 75-91] assigns a desired eigenvalue to a perturbation of this matrix A by a rank-one matrix. In this talk we present some applications of this theorem to control theory. Concretely, we obtain that the poles of the closed-loop control system can be moved to any arbitrary location through state feedback including the case when the system is noncontrollable. A discussion on the eigenstructure of the generalized eigen-subspace is given. Further applications are considered. The above results can be extended when different eigenvalues are changed at the same time.

This contribution is a joint work with Rafael Cantó and Ana M. Urbano (IMM, UPV, Spain) and it was supported by the Spanish DGI grant MTM2010-18228 and the UPV PAID-06-10.

CS14: Inequalities and Upper Bounds

	CS14: Inequalities and Upper Bounds	
Monday, 22.08.2011	Chair: 14	**Room:**
17:00 - 17:20	**Shigeru Furuichi**	
	A matrix trace inequality and its applications to entropy theory	p. 166
17:20 - 17:40	**Antonio Leal-Duarte**	
	Eigenvalue's interlacing inequalities in Matrix Theory	p. 166
17:40 - 18:00	**Takeaki Yamazaki**	
	Riemannian mean and matrix inequalities	p. 167
18:00 - 18:20	**Jiyuan Tao**	
	Some inequalities involving determinants, eigenvalues, and Schur complements in Euclidean Jordan algebras	p. 167
18:20 - 18:40	**Brian Lins**	
	Upper bounds for order-preserving homogeneous maps on cones	p. 168

- end of session-

Shigeru Furuichi
Nihon University

A matrix trace inequality and its applications to entropy theory

Monday, 22.08.2011, 17:00 - 17:20, Room to be filled in later by organizers

In this talk, we give a complete and affirmative answer to a conjecture on matrix trace inequalities for the sum of positive semidefinite matrices. We also apply the obtained matrix trace inequality to derive a kind of the generalized Golden-Thompson inequality in particular case of positive semidefinite matrices and a lower bound of the generalized relative entropy (Tsallis relative entropy) under a ceratin assumption. In addition, we compare the known bounds and the new bounds, for both upper and lower bounds of the generalized relative entropy, respectively.

This contribution is partially joint work with M.Lin (Regina University, Canada).

Antonio Leal-Duarte
Dep. Matemática, University of Coimbra, Portugal

Eigenvalue's interlacing inequalities in Matrix Theory

Monday, 22.08.2011, 17:20 - 17:40, Room to be filled in later by organizers

Based on proofs of interlacing inequalities by Gantmahker and Krein (1935) for oscillatory matrices, and R. C. Thompson for Hermitian matrices we will present a proof of the interlacing inequalities that covers both cases. Such approach allows us to characterize (in terms of eigenvectors) the $n \times n$ matrices with real eigenvalues that possess the interlacing property between the e igenvalues of a certain principal submatrix of order $n-1$ and the eigenvalues of the whole matrix. This is related with the well-known Taussky unification problem.

Takeaki Yamazaki
Toyo University, Japan

Riemannian mean and matrix inequalities

Monday, 22.08.2011, 17:40 - 18:00, Room to be filled in later by organizers

In this talk, some matrix inequalities are introduced. They are extensions of known matrix inequalities, for instance, Ando-Hiai inequality and characterization of chaotic order. These matrix inequalities can be written by using geometric mean $A\sharp_\alpha B$ of two positive invertible matrices A and B defined by

$$A\sharp_\alpha B = A^{\frac{1}{2}}(A^{\frac{-1}{2}}BA^{\frac{-1}{2}})^\alpha A^{\frac{1}{2}}.$$

We will extend known matrix inequalities by using Riemannian mean (or the least squares mean) $G_\delta(A_1,\ldots,A_n)$ of n positive invertible matrices $A_1,\ldots,A_n$ instead of $A\sharp_\alpha B$. In fact, we will obtain Ando-Hiai inequality and characterization of chaotic order for n matrices.

Jiyuan Tao
Loyola University Maryland, USA

Some inequalities involving determinants, eigenvalues, and Schur complements in Euclidean Jordan algebras

Monday, 22.08.2011, 18:00 - 18:20, Room to be filled in later by organizers

In this talk, we present various inequalities in Euclidean Jordan algebras by using Schur complements. Specifically, we show that analogues of the inequalities of Fischer, Hadamard, Bergstrom, Oppenheim, and other inequalities related to determinants, eigenvalues, and Schur complements.

This contribution is joint work with M.S. Gowda (University of Maryland, Baltimore County, USA).

Brian Lins
Hampden-Sydney College

Upper bounds for order-preserving homogeneous maps on cones

Monday, 22.08.2011, 18:20 - 18:40, Room to be filled in later by organizers

Let C be a closed cone in $\mathbf{R}^n$, and suppose that $T : C \to C$ is homogeneous of degree one and order-preserving with respect to the partial ordering induced by C. If C is the positive orthant in $\mathbf{R}^n$, we prove upper bounds on the iterates of T that restrict the location of accumulation points of the discrete dynamical system $x_{k+1} = T(x_k)/||T(x_k)||$. For other closed cones C, we establish similar bounds on T. Connections with nonlinear Perron-Frobenius theory and applications of these results to linear and nonlinear maps are discussed.

This contribution is joint work with Philip Chodrow (Swarthmore University, USA) and William Cole Franks (University of South Carolina, USA).

CS15: Differential and Difference Equations

	CS15: Differential and Difference Equations	
Tuesday, 23.08.2011	Chair: 15	**Room:**
17:00 - 17:20	**Ann-Kristin Baum** *Positivity preserving discretizations of Differential-Algebraic-Equations*	p. 170
17:20 - 17:40	**Ioannis Dassios** *Robust Stability of Linear Matrix Difference Equations of Higher Order*	p. 170
17:40 - 18:00	**Nyamwala Fredrick Oluoch** *Spectral Analysis of Difference Operators With Almost Constant Coefficients*	p. 171

- end of session -

Ann-Kristin Baum
Technische Universität Berlin

Positivity preserving discretizations of Differential-Algebraic-Equations

Tuesday, 23.08.2011, 17:00 - 17:20, Room to be filled in later by organizers

In the simulation of dynamical processes in economy, social sciences, biology or chemistry, the analyzed values typically represent 'real' quantities like money, goods or individuals or the concentration of chemical and biological species. This leads to positive systems, i.e., differential equations that yield a non-negative solution for every non-negative initial value. Beside positivity, such processes often must satisfy additional constraints resulting from limitation of resources, conservation or balance laws and which extend the differential system by accessory algebraic equations.
Solving these differential-algebraic equations (DAE) numerically, we thus need to satisfy the algebraic constraints as well as the positivity condition to obtain physical meaningful results.
In my talk, I will explain how the existing results of unconstrained positive systems can be generalized to DAEs and how the severe stepsize restrictions for Runge-Kutta and Multistep Methods can be relaxed, if the structure of the given problem is exploited more precisely. For unconstrained problems $\dot{x} = Ax + f$, this means to quantify the 'positive impact' of the off-diagonal entries of A, where for constrained systems $E\dot{x} = Ax + f$, we must filter out the positivity providing entries of (E, A). For the algebraic components, I will present conditions for a positive discretization - and that none of the common methods meet them for higher index problems.

Ioannis Dassios
University of Athens, Greece

Robust Stability of Linear Matrix Difference Equations of Higher Order

Tuesday, 23.08.2011, 17:20 - 17:40, Room to be filled in later by organizers

In the perturbation theory of linear matrix difference equations,it is well known that the theory of finite and infinite elementary divisors of regular matrix pencils is complicated by the fact that arbitrarily small perturbations of the pencil can cause them to disappear.In this paper , the perturbation theory of complex Weierstrass cannonical form for regular matrix pencils is investigated.By using matrix pencil theory and the Weierstrass cannonical form of the pencil we obtain bounds for the finite elementary divisors of a perturbed pencil.Moreover we study robust stability of a class of linear matrix difference equations (regular case) of higher order whose coefficients are square constant matrices.

Nyamwala Fredrick Oluoch
Maseno University, Mathematics Department, Kenya

Spectral Analysis of Difference Operators With Almost Constant Coefficients

Tuesday, 23.08.2011, 17:40 - 18:00, Room to be filled in later by organizers

With appropriate smoothness and decay conditions, we show by asymptotic summation that the minimal difference operator with almost constant coefficients is limit point and its self-adjoint extension operator has no singular continuous spectrum and the absolutely continuous spectrum agrees with that of constant coefficient limiting operator.

This contribution is joint work with Horst Behncke (University of Osnabrueck, Germany).

CS16: Information Theory

CS16: Information Theory		
Tuesday, 23.08.2011	Chair: 16	**Room:**
17:00 - 17:20	**Raffaello Seri** *Differentials of Eigenvalues and Eigenvectors under Non-standard Normalizations with Applications to Search Engine Rankings*	p. 173
17:20 - 17:40	**André Klein** *Statistical Distance Measures and the Fisher Information Matrix*	p. 173
17:40 - 18:00	**Pedro Massey** *Optimal reconstruction systems for erasures and for the q-potential*	p. 174

- end of session -

Raffaello Seri
Università degli Studi dell'Insubria

Differentials of Eigenvalues and Eigenvectors under Nonstandard Normalizations with Applications to Search Engine Rankings

Tuesday, 23.08.2011, 17:00 - 17:20, Room to be filled in later by organizers

Consider a matrix $\mathbf{A}_0$ obtained as an infinitesimal perturbation of another matrix $\mathbf{A}_0$. We obtain the first two differentials of a simple eigenvalue λ and the corresponding eigenvector $\mathbf{u} = \mathbf{u}(\mathbf{A})$ of $\mathbf{A}$, around the corresponding quantities λ_0 and $\mathbf{u}_0 = \mathbf{u}(\mathbf{A}_0)$ of the ideal system $\mathbf{A}_0 \cdot \mathbf{u}_0 = \lambda_0 \cdot \mathbf{u}_0$. As concerns the differentials of the eigenvector, we allow for nonstandard normalizations (normalization through the L_1 and L_2 norms, mass normalization, etc.). Through this result, we are able to recover in a unified way the differentials of some quantities (the priority vector of the Analytic Hierarchy Process, the ergodic distribution of Markov chains, the growth rate of ecological stage-structured models) already obtained in the literature. The result is then applied to derive the sensitivities of several search engines (PageRank, HITS, SALSA, Randomized HITS, Randomized SALSA, Exponentiated Inputs to HITS, Query-independent Modified HITS) with respect to the quantities involved in their calculation.

This contribution is joint work with Christine Choirat (Universidad de Navarra, Spain) and Michele Bernasconi (Università Ca' Foscari Venezia, Italy).

André Klein
University of Amsterdam, The Netherlands

Statistical Distance Measures and the Fisher Information Matrix

Tuesday, 23.08.2011, 17:20 - 17:40, Room to be filled in later by organizers

We display some results on statistical distance measures and its interaction with some structured matrices. In a statistical context the straight-line or Euclidean distance is unsatisfactory. This is because the coordinates or variables represent measurements that are subject to random fluctuations of different magnitudes. It is therefore important to consider a distance that takes the variability of these variables into account when determining its distance from a fix point. We consider the statistical distance for the case the x_i measurements do not vary independently of the x_j measurements. A rotation of the n-dimensional coordinate system through an angle ψ is considered while keeping the scatter of points given by the data fixed and label the rotated axes $\widetilde{x}_1,\ \widetilde{x}_2, \ldots, \widetilde{x}_n$. The statistical distance measure obtained is determined entirely by the size of statistical fluctuations through the covariances. It is then identified with an appropriate quadratic form. We shall interconnect the Fisher information matrix to the statistical distance measures and we involve the Sylvester resultant matrix and emphasize the role structured matrices play in generalizing and better understanding the distance measures under study.

This contribution is joint work with Peter Spreij (University of Amsterdam) and Guy Mélard (University of Brussels).

Pedro Massey
Universidad Nacional de La Plata & IAM-CONICET, Argentina

Optimal reconstruction systems for erasures and for the q-potential

Tuesday, 23.08.2011, 17:40 - 18:00, Room to be filled in later by organizers

In this talk we consider the q-potential as an extension of the Benedetto-Fickus frame potential, defined on reconstruction systems - that are a subclass of G-frames - and show that protocols are the minimizers of this potential under certain restrictions. We describe the structure of optimal protocols with respect to 1 and 2 lost packets where the worst (normalized) reconstruction error is computed with respect to a compatible unitarily invariant norm. We describe necessary and sufficient (spectral) conditions, that we call q-fundamental inequalities, for the existence of protocols with prescribed properties by relating this problem to Klyachko's and Fulton's theory on sums of hermitian operators and relate that problem with the notion of extended majorization between hermitian matrices.

CS17: Algebraic Structures and Matrix Theory

	CS17.1: Algebraic Structures and Matrix Theory (PART I)	
Monday, 22.08.2011	Chair: 17.1	**Room:**
17:00 - 17:20	**Antonio J. Calderon Martin**	
	On the structure of split Lie algebras and split Lie triple systems	p. 178
17:20 - 17:40	**Alberto Borobia**	
	Matrix completion problems over integral domains: the case with a diagonal of prescribed blocks	p. 178
17:40 - 18:00	**Rachel Quinlan**	
	Affine spaces of matrices with bounded rank, and a dual property	p. 179
18:00 - 18:20	**Antonio Cicone**	
	Evaluating the Joint Spectral Radius	p. 179
18:20 - 18:40	**Alexander Guterman**	
	Monotone transformations on matrix spaces	p. 180
	CS17.2: Algebraic Structures and Matrix Theory (PART II)	
Tuesday, 23.08.2011	Chair: 17.2	**Room:**
17:00 - 17:20	**Maria Manuel Torres**	
	Metric structure of critical orbital sets	p. 180
17:20 - 17:40	**Mariano Ruiz**	
	Duality in reconstruction systems	p. 181

- to be continued -

CS17.2: Algebraic Structures and Matrix Theory (PART II - continuation)

Tuesday, 23.08.2011	Chair: 17.2	**Room:**
17:40 - 18:00	**Peter Šemrl** *A localization technique for linear preservers*	p. 181
18:00 - 18:20	**Klemen Šivic** *Varieties of triples of commuting matrices*	p. 182
18:20 - 18:40	**Néstor Thome** *A matrix equation containing a periodic matrix*	p. 182

CS17.3: Algebraic Structures and Matrix Theory (PART III)

Thursday, 25.08.2011	Chair: 17.3	**Room:**
17:40 - 18:00	**Bryan L. Shader** *Potentially Nilpotent and Spectrally Arbitrary Sign Patterns*	p. 183
18:00 - 18:20	**Pauline van den Driessche** *Sign Patterns that Require or Allow Particular Refined Inertias*	p. 183
18:20 - 18:40	**Sergey Savchenko** *The rate of convergence of the spectral radii of finite principal submatrices and the spectral properties of the original infinite irreducible matrix with non-negative entries*	p. 184

- to be continued -

CS17.4: Algebraic Structures and Matrix Theory (PART IV)

Friday, 26.08.2011	Chair: 17.4	**Room:**
15:30 - 15:50	**Chi-Kwong Li** *Linear algebra techniques in Quantum Information Science*	p. 184
15:50 - 16:10	**Ulrica Wilson** *Eventual Properties of Matrices*	p. 185
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Antonio J. Calderon Martin
University of Cadiz. Spain.

On the structure of split Lie algebras and split Lie triple systems

Monday, 22.08.2011, 17:00 - 17:20, Room to be filled in later by organizers

A splitting Cartan subalgebra H of a Lie algebra L is defined as a maximal abelian subalgebra of L satisfying that the adjoint mappings $ad(h)$ for $h \in H$ are simultaneously diagonalizable. If L contains a splitting Cartan subalgebra H, then L is called a split Lie algebra.
Classical examples of split Lie algebras are the L^*-algebras $\mathcal{M}_{\mathcal{A}}(\mathbf{C})$ of all of the $\mathcal{A} \times \mathcal{A}$-matrixes over the complex numbers such that $\sum ||a_{ij}|| < \infty$. This example can be extended to the more general case $\mathcal{M}_{\mathcal{A}\times\mathcal{B}}(\mathbf{C})$ via a split Lie triple system construction. We also have as example $Skw(\mathcal{M}_{\mathcal{A}}(\mathbf{C}), t)$ where t denotes the transposition operator. We develop techniques of connections of roots for split Lie algebras with symmetric root systems. We show that any of such algebras L is of the form $L = \mathcal{U} + \sum_j I_j$ with $\mathcal{U}$ a subspace of the abelian Lie algebra H and any I_j a well described ideal of L, satisfying $[I_j, I_k] = 0$ if $j \neq k$. Under certain conditions, the simplicity of L is characterized and it is shown that L is the direct sum of the family of its minimal ideals. These techniques are extended to the frameworks of split Lie triple systems and split twisted inner derivation triple systems.

Alberto Borobia
Dpto. Matemáticas, UNED, 28040 Madrid, Spain

Matrix completion problems over integral domains: the case with a diagonal of prescribed blocks

Monday, 22.08.2011, 17:20 - 17:40, Room to be filled in later by organizers

Let $\Re$ be an arbitrary integral domain, let $\Lambda = \{\lambda_1, \dots, \lambda_n\}$ be a multiset of elements of $\Re$, let σ be a permutation of $\{1, \dots, k\}$, let $n_1, \dots, n_k$ be positive integers such that $n_1 + \cdots + n_k = n$, and for $r = 1, \dots, k$ let $A_r \in \Re^{n_r \times n_{\sigma(r)}}$. We are interested in the problem of finding a block matrix $Q = [Q_{rs}]_{r,s=1}^k \in \Re^{n \times n}$ with spectrum Λ and such that $Q_{r\sigma(r)} = A_r$ for $r = 1, \dots, k$. Cravo and Silva [G. Cravo, F. Silva, Eigenvalues of matrices with several prescribed blocks II, Linear Algebra Appl. 364 (2003) 81–89] completely characterized the existence of such a matrix when $\Re$ is a field. In this work we solve the problem when $\Re$ is an integral domain with the following exceptions: *(i)* $k = 2$, *(ii)* $k \geq 3$, $\sigma(r) = r$ and $n_r > n/2$ for some r. More interestingly, we provide a finite step algorithm to construct an specific matrix Q with spectrum Λ.

This contribution is joint work with Roberto Canogar (Dpto. Matemáticas, UNED, 28040 Madrid, Spain).

Rachel Quinlan
National University of Ireland, Galway

Affine spaces of matrices with bounded rank, and a dual property

Monday, 22.08.2011, 17:40 - 18:00, Room to be filled in later by organizers

The following question, arising from a construction involving automorphisms of finite p-groups, was posed by F. Szechtman in 2003 : *for a vector space V of dimension n over a field F, what is the minimum possible dimension of a (non-linear) affine subspace of $\mathrm{End}_F(V)$ that contains elements annihilating all hyperplanes of V?* This question is equivalent, under a duality arising from the trace bilinear form on $M_n(F)$, to the problem of determining the maximum possible dimension of a linear subspace of $M_n(F)$ in which no element possesses a non-zero eigenvalue that belongs to the field F. This talk will explain this duality and show how it can be used to solve both of the problems mentioned above, giving the respective answers $\frac{n(n+1)}{2} - 1$ and $\frac{n(n-1)}{2}$, independently of the field under consideration.
The duality relation will then be explored in a wider context involving affine spaces of square and rectangular matrices that have special rank properties and special covering properties. One application that will be discussed is to the problem of characterizing partial matrices whose completions have ranks satisfying a prescribed lower bound.

Antonio Cicone
Michigan State University

Evaluating the Joint Spectral Radius

Monday, 22.08.2011, 18:00 - 18:20, Room to be filled in later by organizers

Let $\mathcal{F}$ be a finite set of matrices in $R^{n\times n}$. The *Joint Spectral Radius* of $\mathcal{F}$ is the generalization of the spectral radius notion. The JSR evaluation proves to be useful in many contexts like in the construction of wavelets of compact support, in analysing asymptotic behaviours of linear difference equations solutions with variable coefficients and many others. However this quantity proves in general to be hard to compute. Gripenberg in [G. Gripenberg, Computing the joint spectral radius, 1996] proposed an algorithm for computing lower bounds and upper bounds to $\rho(\mathcal{F})$ making use of a four member inequality and a branch & bound technique, while Blondel et al. developed a conic programming approach that proves to be helpful in the quest for a tighter upper bound [V. D. Blondel, R. M. Jungers, V. Y. Protasov, Joint spectral characteristics of matrices: a conic programming approach, 2010]. In this talk we describe a new method to compute the JSR that, following the ideas of Gripenberg and Blodel at al., makes use of semidefinite lifting procedures, ellipsoidal norms, conic programming methods, bisection and branch & bound techniques to achieve in a finite number of steps and up to a desired arbitrarily high precision lower bounds and upper bounds to $\rho(\mathcal{F})$. We show the performance of this new algorithm compared with the Gripenberg's one.
This contribution is joint work with V.Y.Protasov (Moscow State University, Russia).

Alexander Guterman
Moscow State University

Monotone transformations on matrix spaces

Monday, 22.08.2011, 18:20 - 18:40, Room to be filled in later by organizers

We present our recent results on the characterization of monotone transformations on matrix spaces with respect to various matrix partial orders. In particular it turns out that the thinner the matrix partial order under consideration is the smaller is the class of corresponding monotone transformations.

Maria Manuel Torres
Universidade de Lisboa, Faculdade de Ciências, Departamento de Matemática, CELC, Portugal

Metric structure of critical orbital sets

Tuesday, 23.08.2011, 17:00 - 17:20, Room to be filled in later by organizers

The work [Pedro C. Silva, Maria M. Torres, "Tensors, Matchings and Codes", to appear in LAA] is a continuation of the papers [J. A. Dias da Silva, Maria M. Torres, "On the orthogonal dimension of orbital sets", LAA, 2005] and [J. A. Dias da Silva, Maria M. Torres,"A combinatorial approach to the orthogonality on critical orbital sets", LAA, 2006] where combinatorial necessary and sufficient conditions for orthogonality in critical orbital sets of symmetry classes of tensors were obtained and some values for their orthogonal dimension were computed. In the particular case of the hook partition $(2, 1^{n-2})$ it was proved that the orthogonal dimension of the critical orbital sets is $\lfloor \frac{n}{2} \rfloor$. In the same direction, we completely describe the metric structure of the critical orbital sets associated to the partition $(2, 1^{n-2})$. We show that these sets are actually crystallographic root systems with Dynkin diagram A_{n-1} and we describe the decomposable symmetrized tensors in terms of its simple roots. As a corollary we reobtain the orthogonal dimension $\lfloor \frac{n}{2} \rfloor$ as the independence number of A_{n-1}.

This contribution is joint work with Pedro C. Silva (ISA-UTL Lisbon, Portugal).

Mariano Ruiz
Universidad Nacional de La Plata & IAM-CONICET, Argentina

Duality in reconstruction systems

Tuesday, 23.08.2011, 17:20 - 17:40, Room to be filled in later by organizers

In this talk, we consider reconstruction systems (RS's), which are G-frames in a finite dimensional setting, and that includes the fusion frames as projective RS's. We describe the spectral picture of the set of RS operators for the projective systems with fixed weights. We also introduce a functional defined on dual pairs of RS's, called the joint potential, and we study the structure of the minimizers of this functional. In the case of irreducible RS's the minimizers are characterized as the tight systems. In the general case we give spectral and geometric characterizations of the minimizers of the joint potential.

This contribution is joint work with Pedro Massey (UNLP-IAM, Argentina) and Demetrio Stojanoff (UNLP-IAM, Argentina).

Peter Šemrl
University of Ljubljana

A localization technique for linear preservers

Tuesday, 23.08.2011, 17:40 - 18:00, Room to be filled in later by organizers

We introduce a new general technique for solving linear preserver problems. The idea is to localize a given linear preserver ϕ at each non-zero vector. In such a way we get vector-valued linear maps on the space of matrices which inherit certain properties from ϕ. If we can prove that such induced maps have a standard form, then ϕ itself has either a standard form or a very special degenerate form. We apply this technique to characterize linear preservers of full rank. Using this technique we further reprove two classical results describing the general form of linear preservers of rank one and linear preservers of the unitary (or orthogonal) group.

This contribution is joint work with Leiba Rodman (College of William and Mary, USA).

Klemen Šivic
Institute of Mathematics, Physics and Mechanics, Ljubljana, Slovenia

Varieties of triples of commuting matrices

Tuesday, 23.08.2011, 18:00 - 18:20, Room to be filled in later by organizers

The set $C(d, n)$ of all d-tuples of commuting $n \times n$ matrices over an algebraically closed field F of characteristic zero can be viewed as an affine variety in F^{dn^2} defined by $\binom{d}{2}n^2$ quadratic equations which entry-wise describe the commutativity of matrices. By classical result of Motzkin and Taussky the variety $C(2, n)$ is irreducible for each n. On the other hand, for $d \geq 4$ Gerstenhaber proved that $C(d, n)$ is reducible if $n \geq 4$. The question of irreducibility of varieties of commuting triples is still an open problem. It has been shown that $C(3, n)$ is irreducible for $n \leq 8$ and reducible for $n \geq 30$. The problem of irreducibility of $C(3, n)$ is equivalent to that whether $C(3, n)$ equals to the Zariski closure of the set of all triples of generic commuting matirces (i.e. matrices having n distinct eigenvalues). Using simultaneous commutative approximation of triples of matrices by triples of generic matrices we prove that the varieties $C(3, 9)$ and $C(3, 10)$ are irreducible. We study also a related problem of irreducibility of the varieties of pairs of commuting matrices in the centralizers of r-regular matrices (i.e. matrices having at most r-dimensional eigenspaces only). Neubauer and Sethuraman proved that this variety is irreducible in 2-regular case. We show that the same is true in 3-regular case, but on the other hand, there exists 5-regular matrix with reducible variety of commuting pairs in its centralizer.

Néstor Thome
Universitat Politècnica de València, Spain

A matrix equation containing a periodic matrix

Tuesday, 23.08.2011, 18:20 - 18:40, Room to be filled in later by organizers

It is well-known that periodic matrices are a generalization of the involutory ones. On the other hand, an extension of the class of idempotent, tripotent, etc. has been introduced in [L. Lebtahi, N. Thome. *Characterizations of $\{K, s+1\}$-potent matrices and applications.* to appear in Linear Algebra and its Applications], namely the $\{R, s+1\}$-potent matrices, where R denotes an involutory matrix. All these matrices have been used in many applications in different areas. When R is a periodic matrix, a block diagonalization for a matrix A when $AR = RA$ was stated in [J. R. Weaver. *Block diagonalization for a matrix A when $AR = RA$ and $R^k = I$*, Proceedings of the 16th Conference of the International Linear Algebra Society, Pisa, 2010.]. In this paper we will study a new kind of matrices combining both situations. Some properties of these matrices using the spectral theory will give some information about their behavior.

This contribution is joint work with Leila Lebtahi (Universitat Politècnica de València, Spain) and James Weaver (University of West Florida, Pensacola, FL USA).

Bryan L. Shader
University of Wyoming, USA

Potentially Nilpotent and Spectrally Arbitrary Sign Patterns

Thursday, 25.08.2011, 17:40 - 18:00, Room to be filled in later by organizers

We discuss several new results concerning potentially nilpotent matrices and spectrally arbitrary sign patterns. In particular, a parametrization of the irreducible, tridiagonal nilpotent matrices is given and investigated, a connection between the Nilpotent-Jacobi method and centralizers of matrices is given, and the T_n conjecture

> The n by n sign pattern T_n with $+$'s in the $(1,1)$ and superdiagonal positions, $-$'s in the (n,n) and subdiagonal postions, and 0's elsewhere, is spectrally arbitrary for all $n \geq 2$

is proven.

This contribution is joint work with Colin Garnett (University of Wyoming, USA) and Paul Terwilliger (University of Wyoming, USA).

Pauline van den Driessche
Department of Math. and Stats, University of Victoria, Victoria, BC, Canada

Sign Patterns that Require or Allow Particular Refined Inertias

Thursday, 25.08.2011, 18:00 - 18:20, Room to be filled in later by organizers

An $n \times n$ *sign pattern* $\mathcal{S}_n = [s_{ij}]$ is a matrix that has entries in $\{+, -, 0\}$, and $Q(\mathcal{S}_n) = \{A = [a_{ij}] \in M_n(\mathbb{R}) \mid \text{sign } a_{ij} = s_{ij} \text{ for all } i, j\}$ is its associated *sign pattern class*. The *refined inertia* $ri(A)$ of a real $n \times n$ matrix A is the ordered $4-$tuple $(n_+, n_-, n_z, 2n_p)$ such that n_+ (resp. n_-) is the number of eigenvalues with positive (resp. negative) real part, and n_z (resp. $2n_p$) is the number of zero eigenvalues (resp. nonzero pure imaginary eigenvalues) of A.
To relate the possibility of Hopf bifurcation in an ordinary differential equation system to refined inertia, let $\mathbb{H}_n = \{(0, n, 0, 0), (0, n-2, 0, 2), (2, n-2, 0, 0)\}$ for $n \geq 2$. A sign pattern $\mathcal{S}_n$ *requires refined inertia* $\mathbb{H}_n$ if $\mathbb{H}_n = \{ri(A) \mid A \in Q(\mathcal{S}_n)\}$, and $\mathcal{S}_n$ *allows refined inertia* $\mathbb{H}_n$ if $\mathbb{H}_n \subseteq \{ri(A) \mid A \in Q(\mathcal{S}_n)\}$. This talk focuses on the questions: Which $n \times n$ sign patterns require/allow $\mathbb{H}_n$? Some results, conjectures and open questions are presented.

This is research with a group (many of whom are young researchers) formed at a CBMS workshop at Iowa State University, and includes Mary Allison, Elizabeth Bodine, Louis Deaett, Colin Garnett, Olga Kurth, Judith McDonald, Reshmi Nair, Dale Olesky.

Sergey Savchenko
L.D. Landau Institute for Theoretical Physics, Russian Academy of Sciences

The rate of convergence of the spectral radii of finite principal submatrices and the spectral properties of the original infinite irreducible matrix with non-negative entries

Thursday, 25.08.2011, 18:20 - 18:40, Room to be filled in later by organizers

Let A be an irreducible (finite or infinite) nonnegative matrix with index-set $V(A)$ and $\lambda_{max}(A)$ be the supremum of the spectral radii of its finite principal submatrices. We say that a digraph D with vertex-set $V(D)$ admits a finite cycle-passage domain if there exists a finite subset $W \subset V(D)$ such that any cycle of D contains at least one vertex of W. In other words, $D - W$ has no cycles at all. By definition, the vertex-set of the digraph $D(A)$ of A coincides with $V(A)$ and (i, j) is an arc in $D(A)$ iff the (i, j)th entry of A is not equal to zero. We prove that if $D(A)$ admits a finite cycle-passage domain, then the existence of an infinite sequence of finite principal submatrices A_n of order n with $\lambda_{max}(A) - \lambda_{max}(A_n) = o(n^{-1})$ means that A is recurrent. However, as we show, in the general case, the fast convergence of $\lambda_{max}(A_n)$ to $\lambda_{max}(A)$ does not imply that A admits a positive eigenvector associated with $\lambda_{max}(A)$.

Chi-Kwong Li
Affiliation Department of Mathematics, College of William and Mary, Virginia 23185

Linear algebra techniques in Quantum Information Science

Friday, 26.08.2011, 15:30 - 15:50, Room to be filled in later by organizers

We describe the use of linear algebra techniques such matrix inequalities, numerical ranges, completely positive maps to study problems in quantum information science such as quantum error correction, quantum operations, separability. Recent results and open problems will be discussed.

Ulrica Wilson
Morehouse College

Eventual Properties of Matrices

Friday, 26.08.2011, 15:50 - 16:10, Room to be filled in later by organizers

Eventually positive matrices are characterized by Perron-Frobenius properties and while there is no such characterization for eventually nonnegative matrices, there is much that can be said. Since their introduction, both of these eventual properties of matrices have been studied extensively. In particular, there are subsets of eventually nonnegative matrices, such as strongly eventually nonnegative (SEN) matrices that have nice characterizations. Eventually r-cyclic matrices were introduced to study SEN matrices. In this talk we discuss the spectral structure of eventually r-cyclic matrices and discuss some other eventual properties of matrices.

This contribution is joint work with Leslie Hogben (Iowa State University, USA) .

Rafig Agaev
Institute of Control Sciences of the Russian Academy of Sciences, Moscow, Russia

A regularized limit of a decomposable stochastic matrix

Friday, 26.08.2011, 16:10 - 16:30, Room to be filled in later by organizers

A stochastic matrix P is called *regular* if it is aperiodic and indecomposable. If P is regular, then $P^\infty = \lim_{k\to\infty} P^k$ exists and has rank one. Let P be decomposable. In a number of applications including the DeGroot consensus model, it is required to attach to P a suitable rank-one "limiting" stochastic matrix. Consider the orthogonal projection S of $\mathbb{R}^n$ onto the subspace T_P such that P^∞ (which exists whenever P is aperiodic) maps T_P onto the linear span of $\mathbf{1} = (1\dots1)^{\mathrm{T}}$. Next, define $\overset{\infty}{P} = P^\infty S$ and call it the *regularized limit of* $\{P^k\}$. We show that $T_P = \mathcal{R}(L) \oplus \{\alpha\mathbf{1} \mid \alpha \in \mathbb{R}\}$, where $L = I - P$ is the Kirchhoff matrix of the corresponding digraph. In case L is represented in a block triangular form with the essential states numbered first, we construct a matrix Z by replacing the first column of L by $\mathbf{1}$ and the first column of each ith, $i > 1$, diagonal block by $\pi^{i-1} - \pi^i$, where π^i is determined by the stationary vector of the ith diagonal block of P. The main properties of $\overset{\infty}{P}$ are as follows:
Theorem. 1. $\overset{\infty}{P}$ *is a stochastic rank-one matrix.*
2. Z *is nonsingular and each row of* $\overset{\infty}{P}$ *coincides with the first row of* Z^{-1}.
The paper also deals with other properties of $\overset{\infty}{P}$ and generalizes it for a periodic P.
This contribution is joint work with Pavel Chebotarev (Institute of Control Sciences of the Russian Academy of Sciences, Moscow, Russia).

Bas Lemmens
University of Kent, United Kingdom

Continuity of the cone spectral radius

Friday, 26.08.2011, 16:30 - 16:50, Room to be filled in later by organizers

It is well known that a significant part of the spectral theory of positive linear operators on a closed cone K in a Banach space can be extended to maps $f\colon K \to K$ that are order-preserving and homogeneous of degree one. For such maps there exists the notion of the **(Bonsall) cone spectral radius**, $r_K(f)$, and under suitable compactness conditions on f there exists a corresponding eigenvector in K.
In this talk I will discuss some new results concerning the continuity of the cone spectral radius. Among others we will see that if $f\colon K \to K$ is a continuous, compact, order-preserving, homogenous map and there exist $0 < a_1 < a_2 < a_3 < \cdots$ with $a_k \to r_K(f)$ and the a_i's are **not** in the spectrum of f, then f has a continuous cone spectral radius. For finite dimensional cones it is unknown if such a sequence of a_i's always exists. I will also discuss some partial results concerning this problem.

This contribution is joint work with Roger Nussbaum (Rutgers University, USA).

Lajos Molnár
University of Debrecen, Hungary

Order automorphisms on positive definite operators and some applications

Friday, 26.08.2011, 16:50 - 17:10, Room to be filled in later by organizers

In this talk we determine the structure of order automorphisms of the set of all positive definite operators on a complex Hilbert space with respect to the usual order and to the chaotic order. Next we apply those results to the following problems: 1) description of all bijective transformations on the space of nonsingular density operators (quantum states) which preserve the Umegaki or the Belavkin-Staszewski relative entropy; 2) characterization of the logarithmic product as the essentially unique binary operation on the set of positive definite operators that makes it an ordered commutative group with respect to the chaotic order. L. Molnár, *Order automorphisms on positive definite operators and a few applications,* Linear Algebra Appl. **434** (2011), 2158-2169.

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