SPEAKER: **Jim Agler**, UC San Diego

TITLE: The Caratheodory-Julia Theorem on the Bidisk via Network Realization Theory

ABSTRACT: In an influential paper from the 70s, “The Characteristic Functions of Operator Theory and Electrical Network Realization”, Bill Helton was the first to point out that the main realizability theorem of network systems theory was equivalent to the representation of Shur functions on the unit disc via the characteristic functions of Hilbert space contractions. This paper and other work of Bill from the period, influenced a generation of young operator theorists, including myself, to work on problems more closely connected to the engineering community. In this talk, based on joint work with John McCarthy and Nicolas Young, I shall show how the realization theorem, when generalized to two variables, allows one to work out in a straight forward manner an extension of the classical Caratheodory-Julia theory to the bidisk.

SPEAKER**: Jeff Allen**, SPAWAR

TITLE: H^{∞} Engineering and Impedance Matching

SPEAKER: **Joseph A. Ball**, Virginia Tech

TITLE: Multidimensional circuit synthesis and multivariable dilation theory

ABSTRACT: The fact that a rational matrix-valued inner function on the unit disk has a conservative (or unitary) finite-dimensional transfer-function realization (i.e., can be realized as the scattering function of a discrete-time lossless circuit) was discovered independently in the circuit-theory and operator-theory communities, going back at least to the 1960s. It is now known that an analogous story holds for the Schur class on the bidisk but, in the case of the polydisk in more than two variables, such results can hold only for inner functions in the more restrictive Schur-Agler class. It this talk we review how this multivariable generalization was also discovered independently in the circuit-theory and operator-theory communities, and indicate connections with dilation theory, completely positive maps and sums-of-squares problems.

SPEAKER: **Estelle Basor,** American Institute of Mathematics

TITLE: Determinants of perturbations of finite Toeplitz matrices

ABSTRACT: The Strong Szeg\"{o} Limit Theorem describes the asymptotic behavior of the determinants of finite Toeplitz matrices as the size of the matrices become large. This talk will outline a proof of the theorem based on a simple observation made by Bill Helton. Some recent extensions of the theorem will be discussed and also their applications to random matrix theory.

SPEAKER: **Bob Bitmead,** UC San Diego

TITLE: A boundary interpolation problem arising in jet engine controller certification

ABSTRACT: A problem arising in the certification of multi-input/multi-output jet-engine-controller pairs will be described. The issue concerns the calculation of positive definite weighting matrices which scale the generalized stability margin. This is done at a sequence of distinct frequency points on the unit circle based on experimentally measured data. The issue is to ensure that a rational matrix function can be found which is stable, stably invertible, positive definite on the entire unit circle and interpolates the weighting functions at the frequency values. We will establish that this can be done and that Bill Helton and his colleagues are to blame. But most of the time will be devoted to setting up the problem and its practical connections.

SPEAKER: **Juan Camino,** U of Campinas

TITLE: Optimization over matrix inequalities

SPEAKER: **Jie Chen,** UC Riverside

TITLE: Performance of Networked Feedback Systems: Best Tracking and Optimal Power Allocation

ABSTRACT: In this talk I shall present our recent work on tracking problems in a networked feedback setting. While there has been notable advance in the study of stabilization of networked control systems and fundamental limits have been discovered on network characteristics such as channel capacity, quantization precision, etc, required to achieve stabilization, performance problems beyond stabilization prove more challenging and remain largely an untapped area. This work sets out to investigate the tracking performance of networked control systems, wherein we employ an additive white Gaussian noise model for the feedback channel. We derive explicit expressions for the minimal tracking error attainable under the channel constraint, aiming at understanding how the presence of a communication channel may fundamentally constrain the tracking performance. For multi-input multi-output systems, we also find the optimal strategy to allocate the powers of the individual channels to optimize the tracking performance. Additionally, by introducing a scaling factor, which may be interpreted as a simple scheme of joint channel and controller design, we show how the tracking performance may be improved.

SPEAKER: **Raul Curto**, University of Iowa

TITLE: Truncated moment problems with associated finite algebraic varieties

ABSTRACT: **to see the abstract please scroll down to the last page**

SPEAKER**: Ron Douglas,** Texas A&M University

TITLE: Variations on a theme of Beurling

ABSTRACT: Interpretations of the Beurling-Lax-Halmos Theorem on the invariant subspaces of the unilateral shift will be explored using the language of Hilbert modules. Extensions and generalizations will be considered in both the one and multivariate contexts with an emphasis on examples such as the Hardy, Bergman and Drury-Arveson spaces.

SPEAKER: **John Doyle,** Caltech

TITLE: Cardiovascular control, optimization, and functional analysis

ABSTRACT: One of the central and longstanding mysteries in control theory is how Bill Helton always manages to anticipate the hottest topics, from H-infinity to real algebraic geometry. Even more longstanding and central to acute care medicine and cardiology is the mysterious and apparently paradoxical relationship between health and heart rate variability. We will resolve one of these using some familiar ideas, and perhaps some not so familiar.

SPEAKER: **Harry Dym**, The Weizmann Institute of Science, Israel

TITLE: From Szego to non-commutative polynomials

ABSTRACT: Some glimpses of Bill in action over the past 35 years; with emphasis on recent collaboration with Bill and Caleb Meier on the representation of k by k arrays of polynomials in $2k^2$ commuting variables in terms of matrix polynomials.

SPEAKER: **Lawrence Fialkow**, State University of New York New Paltz

TITLE: Tchakaloff's Theorem and Multivariable Moment Problems

ABSTRACT: A theorem of V. Tchakaloff [1957] provides for the existence of cubature rules of prescribed degree for multivariable Lebesgue measure restricted to a compact set. Recently, Bayer and Teichmann [2006] generalized this theorem to positive Borel measures with unbounded support. We discuss some of the ramifications of this result for the Multivariable Truncated K-Moment Problem.

SPEAKER: **Paul Fuhrmann,** Ben-Gurion U of the Negev

TITLE: On the Chinese remainder theorem and interpolation

SPEAKER: **Keith Glover,** University of Cambridge

TITLE: Some computational questions in fault detection and robust stabilization

ABSTRACT: Two representative problems will be discussed. The first relates to a fault detection problem where H-infinity and H-2 criteria result in very different analytic problems. The second concerns robust stabilization of combustion instabilities and where the IQC analysis tools appear to give LMI problems at or beyond current computational limits.

SPEAKER: **Roger Evans Howe,** Yale University

TITLE: Commutators and Traces - Echoes of early work of Bill Helton

ABSTRACT: This talk will review later developments influenced by Bill Helton's work of the early 1970s on operator theory and its connections to index theory, built mainly around the study of traces of commutators and higher commutators.

SPEAKER: **Matt James,** ANU

TITLE: Information States in Control Theory: From Classical to Quantum

ABSTRACT: This talk will discuss the role of information states in optimal control theory. We review how information states are used to enable the use of dynamic programming methods to solve classical stochastic control problems. We then describe a class of measurement feedback optimal control problems for quantum systems, and show how information states may be extended to this context. In particular, in the case of risk-sensitive measurement feedback control of quantum systems, we describe a modification of the Schrodinger equation that plays the role of information state.

SPEAKER: **Rien Kaashoek,** VU University Amsterdam

TITLE: Right invertible analytic Toeplitz operators and optimal solutions to the rational Corona-Bezout equation

ABSTRACT: In this talk operator theory and state space methods are used to derive optimal solutions to the corona type Bezout equation G(z)X(z)=I. Throughout G is a "fat" stable rational matrix function. Among other things our analysis provides a state space formula for the least squares solution and shows that this solution is rational and has McMillan degree less than or equal to the McMillan degree of G. The talk is based on joint work with A.E. Frazho and A.C.M. Ran.

SPEAKER: **Dmitry Kaliuzhnyi-Verbovetskyi,** Drexel University

TITLE: Noncommutative Functions: Algebraic and Analytic Results

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SPEAKER: **Igor Klep,** University of Ljubljana

TITLE: Free Changes of Variables

SPEAKER: **Art Krener,** Naval Postgraduate School

TITLE: The Accessible Sets of Free Nilpotent Control Systems

SPEAKER: **Miroslav Krstic**, UC San Diego

TITLE: Nash Equilibrium Seeking for Games with Unmodeled Payoff Functionals

ABSTRACT: H-infinity control theory pits finitely many (typically two) players in a non-cooperative differential game in which the players' actions are infinite-dimensional. What happens when the dimensionality is reversed, namely, when infinitely many players perform non-cooperative optimization using finite-dimensional actions? I will formulate this problem and propose non-model-based algorithms with which the players seek their individual maximum payoffs using the measurements of only their payoff values but are unaware of the functional forms of any of the players' (including their own) payoffs and of any of the other players' actions. When all the players use such algorithms, the game locally exponentially converges to the underlying functional Nash equilibrium.

SPEAKER: **Salma Kuhlmann**, Schwerpunkt Reelle Geometrie und Algebra, Universitaet Konstanz Germany

TITLE: The General Moment Problem

ABSTRACT: Let *T* be a locally convex topology on V, the countable dimensional polynomial $\mathbb{R}$-Algebra. Let *K* be a closed subset of $\mathbb{R}^n$, and *M* := *QM*(g_1, ... g_s) a finitely generated module in V. We investigate the following question: When is the cone *Pos(K)* (of polynomials nonnegative on *K*) included in the closure of *M*? We give an interpretation of this inclusion w.r.t. representing continuous linear functionals by measures. We discuss several examples and application to Berg's et al "exponentially bounded moment sequences". This is joint work with M. Ghasemi and E. Samei.

SPEAKER: **Sanjay Lall,** Stanford University

TITLE: Rational Functions and Optimal Decentralized Control

ABSTRACT: In this talk we discuss the problem of constructing optimal decentralized control systems, which is an outstanding problem in control theory. We formulate the problem as one of minimizing the norm of a matrix rational function. We analyze when the set of achievable closed-loop maps is convex. For certain problems we show that the optimum is rational, and give explicit state-space formulae.

SPEAKER: **Scott McCullough**, University of Florida

TITLE: Matrix inequalities and convexity

SPEAKER: **William McEneaney**, UC San Diego

TITLE: Idempotent-algebras, dynamic games and max-plus convexity

ABSTRACT: In recent years, idempotent methods (specifically, max-plus methods) were developed for solution of nonlinear control problems. It was found that the most successful idempotent approach, the curse-of-dimensionality-free approach, required only that the addition operation passed through the semigroup (dynamic programming) operator and that some simple functional form (such as the linear form) was also retained under application of the operator. Using this insight, we extend the applicability of idempotent methods to deterministic dynamic games through application of the min-max distributive property. However, this induces a very high curse-of-complexity. We define the space of max-plus hypo-convex functions - functions mapping Euclidean space into the extended reals such that the hypograph is a max-plus convex set. (A reversed ordering makes the use of the term max-plus concave functions somewhat inappropriate.) This is also referred to as the space of subtopical functions. This is a linear space over the min-max semiring. Using a new form of duality, we obtain a countable spanning set consisting of max-plus linear functionals. We define a "cornice" structure. The problem of complexity reduction in the game problem is reduced to optimization of a max-plus hypo-convex function over a cornice. This implies that the optimal complexity reduction is obtained through pruning.

SPEAKER: **Jiawang Nie,** UC San Diego

TITLE: An Exact Jacobian type SDP Relaxation for Polynomial Optimization

ABSTRACT: We study how to minimize polynomial functions over semialgebraic sets. The standard Lasserre type SDP relaxation gives a sequence of lower bounds that converge to global minimum, but usually does not converge within finitely many steps. This lecture proposes a new type SDP relaxation that uses Jacobian of defining polynomials. Under some generic conditions of nonsingularity and achievability of minimum, this new relaxation will generate a sequence of lower bounds that converge to global minimum within fiintely many steps. For the first time, this gives an exact SDP relaxation for polynomial optimization.

SPEAKER: **Pablo Parrilo**, MIT

TITLE: The convex algebraic geometry of rank minimization

ABSTRACT: Optimization problems involving ranks of matrices are of great importance in applied mathematics and engineering. They provide a rich and fruitful interaction between algebraic-geometric concepts and convex optimization, with strong connections and synergies with popular techniques for sparsity minimization like compressed sensing. In this talk we will describe the key results in this exciting research area, highlighting the geometric and conceptual aspects as well as surveying recent work, applications and algorithms.

SPEAKER: **Mihai Putinar,** UC Santa Barbara

TITLE: Helton-Howe trace formula and planar shapes

ABSTRACT: A review of the role of Helton and Howe trace formula in transforming planar shapes and shade functions into Hilbert space entities will focus on: an image reconstruction algorithm, Laplacian Growth dynamics and elimination theory on Riemann surfaces.

SPEAKER: **Leiba Rodman,** College of William and Mary

TITLE: Positive semidefinite cones and completions

ABSTRACT: The talk will emphasize open problems, together with some basic results, in the theory of completions of partial positive semidfinite matrices. In particular, open problems in the context of matrices with entries in a C^*- algebra will be stated.

SPEAKER: **Robert Skelton,** UC San Diego

TITLE: Optimal Complexity in Structures

ABSTRACT: A Traditional approach to structure design involves setting up a nonlinear programming problem that is then solved (one hopes) numerically. Bill and I started an approach to structure design that exploits simple mathematical structure to the extent that some optimization problems can be solved in closed form. Furthermore, this approach leads to an explicit calculation of optimal complexity. These optimal structures have a recognizable form called Tensegrity structures. Helton's Influence on Tensegrity Systems is described.

SPEAKER: **Eduardo Sontag,** Rutgers

TITLE: Transient behavior in adaptation mechanisms

ABSTRACT: Sensory systems in individual living cells, as well as in multi-cellular organisms, employ a variety of adaptation mechanisms in order to produce behaviors that are invariant to certain characteristics of environmental inputs, such as symmetries or background signal levels, while at the same time allowing the extraction of relevant features of these inputs. These mechanisms and behaviors are responsible for phenomena ranging from chemotaxis in bacteria to the logarithmic sensitivities to forces, sounds, and vision in humans revealed through psychophysical measurements.

Much of our recent research has been devoted to the understanding of feedforward and feedback circuits that produce adaptation behavior. While closely related to standard concepts in control theory such as disturbance rejection, completely new questions arise. For example, while the internal model principle (IMP) would predict that feedback systems must be present in order to guarantee robust adaptation, the lack of separation between plant and controller components makes the significance of the IMP questionable. More so, the need to perform coordinate changes to exhibit the internal model (transformations which, if at all possible, require strong nonsingularity and global properties on vector fields) typically leads to uninterpretable variables. Moreover, questions such as the invariance of transient behaviors to symmetries appear not to have been systematically studied in this context. We will discuss one such behavior (fold-invariance) and mention new experimental results that confirm theoretical predictions.

SPEAKER: **Mark Stankus,** Cal Poly San Luis Obispo University

TITLE: On n-symmetric operators

SPEAKER: **Bernd Sturmfels,** UC Berkeley

TITLE: Quartic Curves and Their Bitangents

ABSTRACT: A smooth quartic curve in the projective plane has 36 inequivalent representations as a symmetric determinant of linear forms and 63 representations as a sum of three squares. We show how to compute these representations from the 28 bitangents of the curve, with special emphasis on the case, featured in the celebrated work of Helton and Vinnikov, when the real curve consists of two nested ovals. This is joint work with Daniel Plaumann and Cynthia Vinzant.

SPEAKER: **Allen Tannenbaum**, Georgia Institute of Technology

TITLE: Optimal Mass Transport for the Registration of Medical Imagery

ABSTRACT: In this talk, we will outline some recent work using the theory of optimal mass transport for surface warping and image registration. The mass transport problem was rst formulated by Gaspar Monge in 1781, and concerned finding the optimal way, in the sense of minimal transportation cost, of moving a pile of soil from one site to another. This problem was given a modern formulation in the work of Kantorovich, and is now known as the "Monge-Kantorovich problem." The registration problem is one of the great challenges that must be addressed in order to make image- guided surgery a practical reality. Registration is the process of establishing a common geometric reference frame between two or more data sets obtained by possibly different imaging modalities. In the context of medical imaging, this is an essential technique for improving preoperative and intraoperative information for diagnosis and image-guided therapy. Registration has a substantial recent literature devoted to it, with numerous approaches effective in varying situations, and ranging from optical flow to computational uid dynamics to various types of warping methodologies. The method we discuss in this talk is designed for elastic registration, and is based on an optimization problem built around the L2 Monge-Kantorovich distance taken as a similarity measure. The constraint that we put on the transformations considered is that they obey a mass preservation property. Thus, we are matching *mass densities* in this method, which may be thought of as weighted areas in 2D or weighted volumes in 3D. We will assume that a rigid (non-elastic) registration process has already been applied before applying our scheme. Our method has a number of distinguishing characteristics. It is parameter free. It utilizes all of the gray-scale data in both images, and places the two images on equal footing. It is thus symmetrical, the optimal mapping from image A to image B being the inverse of the optimal mapping from B to A. It does not require that landmarks be specified. The minimizer of the distance functional involved is unique; there are no other local minimizers. Finally, it is specifically designed to take into account changes in density that result from changes in area or volume. We believe that this type of elastic warping methodology is quite natural in the medical context where density can be a key measure of similarity, e.g., when registering the proton density based imagery provided by MR. It also occurs in functional imaging, where one may want to compare the degree of activity in various features deforming over time, and obtain a corresponding elastic registration map. A special case of this problem occurs in any application where volume or area preserving mappings are considered.

SPEAKER: **Rekha Thomas,** University of Washington

TITLE: Generalized Lifts of Polytopes

SPEAKER: **Hugo J. Woerdeman,** Drexel University

TITLE: A New Spasity -Targeting Iterative Thresholding Algorithm for Inverse Problems

INGRID DAUBECHIES, HUGO J. WOERDEMAN (speaker), AND SERGEY VORONIN

ABSTRACT: In this paper we propose a variation of the soft-thresholding algorithm for finding sparse solutions of the equation Ax = b, where as the sparsity of the iterate increases the penalty function changes as well. In this approach, sufficiently large entries in a sparse iterate are left untouched. The numerical result indicate that the number of iterations to find a solution is substantially less than the traditional soft-thresholding algorithm.

SPEAKER: **Nicholas Young,** Leeds University

TITLE: Some solvable cases of mu-synthesis

ABSTRACT: The mu-synthesis problem is a generalization of some classical interpolation problems, such as the Nevanlinna-Pick problem. It arises in control engineering, in the context of the stabilization of plants in the presence of structured uncertainty. In the classical cases there are elegant solvability criteria, but in almost all other cases we lack a comparable analytic theory. I will describe three very special cases of mu-synthesis (for 2 by 2 matrix functions) in which analysis is possible. The talk will be based mainly on joint work with Jim Agler.

Truncated moment problems with associated finite algebraic varieties

Raúl Curto, University of Iowa

Given a collection of real numbers $\beta \equiv \beta^{(2n)} : \beta_{00}, \beta_{10}, \beta_{01}, \cdots, \beta_{2n,0}, \cdots, \beta_{0,2n}$, with $\beta_{00} > 0$, the *truncated moment problem* (TMP) consists of finding a positive Borel measure μ supported in $\mathbb{R}^2$ such that $\beta_{ij} = \int x^i y^j \, d\mu \quad (0 \leq i+j \leq 2n)$; β is called a *truncated moment sequence* (of order $2n$) and μ is called a *representing measure* for β. Naturally associated with each TMP is a moment matrix $M(n) \equiv M(n)(\beta)$, given by $M(n)_{k\ell} := \beta_{k+\ell}$, where $k, \ell \in \mathbb{Z}_+^2$. Corresponding to β, the *Riesz functional* $L \equiv L_\beta : \mathcal{P}_{2n} \longrightarrow \mathbb{R}$ is defined by $L(\sum a_i x^i) := \sum a_i \beta_i$.

For the multisequence β to have a representing measure μ it is necessary for the associated moment matrix $M(n)$ to be positive semidefinite, and for the algebraic variety associated to β, V_β, to satisfy rank $M(n) \leq$ card V_β as well as the following *consistency condition*: if a polynomial $p(x,y) \equiv \sum_{0 \leq i+j \leq 2n} a_{ij} x^i y^j$ vanishes on V_β, then $L(p) = 0$. In joint work with L.A. Fialkow and H.M. Möller, we have proved that for the extremal case (rank $M(n) =$ card V_β), positivity and consistency are sufficient for the existence of a (unique, rank $M(n)$-atomic) representing measure.

In recent joint work with S. Yoo we have considered cubic column relations in $M(3)$ with associated algebraic varieties of cardinality 7 or 8. We first exhibit a class of cubic harmonic polynomials q_7 whose zero sets consist of exactly 7 points (the maximum number of points) and use the above mentioned solution of the extremal moment problem to obtain a necessary and sufficient condition for the existence of a representing measure. This requires a new representation theorem for sextic polynomials in x and y which vanish in the 7-point set $V_\beta \equiv \mathcal{Z}(q_7)$. We use the Division Algorithm to obtain this representation. In a similar way, we study moment matrices $M(3)$ with rank $M(3) =$ card $V(\beta) = 8$.