

M9 : LMI, Optimization and Polynomial Methods

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This is a course for graduate students or researchers with a background in linear algebra, convex optimization and some knowledge in linear control systems. The focus is on semidefinite programming (SDP), or linear matrix inequality (LMI) optimization, and its interplay with semialgebraic geometry, the study of polynomial inequalities.

Outline

The course starts with fundamental mathematical features of linear matrix inequalities:

- Part I.0: general introduction, course outline and material
- Part I.1: historical developments of LMIs, convexity, cones, duality, semidefinite programming

Then we cover latest achievements in semidefinite programming and its interplay with semialgebraic geometry:

- Part I.2: classification of convex semialgebraic sets that can be represented with LMIs and projections of LMIs, lift and project techniques
- Part I.3: primal problem of moments, dual polynomial sum-of-squares decompositions, representations of polynomials positive on semialgebraic sets, Lasserre's hierarchy of LMI relaxations to solve non-convex polynomial optimisation problems

Then we survey polynomial methods in control engineering:

- Part II.1: stability of a polynomial, semialgebraic formulations, geometry of stability conditions
- Part II.2: robust stability of a polynomial
- Part II.3: LMI methods for robust stability and robust stabilization of polynomials, robust fixed-order controller design

Finally, we focus on numerical and software aspects:

- Part III.1: basics of interior-point algorithms, latest achievements in software and solvers for LMIs
- Part III.2: software for polynomial optimization, including polynomial matrix inequalities (PMIs).



Didier Henrion was born in Creutzwald, Northeastern France, in 1971. He received the Engineer's Degree and the Masters' Degree with specialization in control from the Institut National des Sciences Appliquées (INSA), Toulouse, France, in September 1994. From October 1994 to December 1995 he was a research assistant at the Centro de Automatización Industrial of the Universidad Simón Bolívar, Caracas, Venezuela. From February 1996 to December 1998 he was a Ph.D. student at the Ústav Teorie Informace a Automatizace (UTIA, Institute of Information Theory and Automation), Prague, Czech Republic. From October 1996 to August 1999 he was a Ph.D. student at the Laboratoire d'Analyse et d'Architecture des Systèmes (LAAS, Laboratory of Analysis and Architecture of Systems) of the Centre National de la Recherche Scientifique (CNRS, National Center for Scientific Research) in Toulouse, France. He received the Ph.D. degree from the Academy of Sciences of the Czech Republic in December 1998, the Ph.D. degree from INSA Toulouse in October 1999, the French Habilitation degree from the Université Paul Sabatier de Toulouse in December 2007, and the "Docent" (Czech Habilitation) degree from the Ceske Vysoke Ucení Technické v Praze (Czech Technical University in Prague) in June 2008. Since 2000 Didier Henrion has been a CNRS researcher at LAAS. He is also holding a secondary

appointment as a researcher at the Department of Automatic Control of the Faculty of Electrical Engineering of the CVUT, Czech Technical University in Prague. In 2004 he was awarded the Bronze Medal from CNRS. Didier Henrion has been an Associate Editor at the Conference Editorial Board of the IEEE Control Systems Society (from 1999 to 2004), for the IFAC journal *Automatica* (from 2003 to 2009), for the EUCA European Journal of Control (from 2005 to 2008), for the IEEE Transactions on Automatic Control (from 2005 to 2008), and for the Czech journal *Kybernetika* (from 2008 to 2012). He has been chairing the IEEE Technical Committee on Computer Aided Control System Design (since 2004), vice-chairing the IFAC Technical Committee on Control Design (from 2003 to 2008), and he has been a member of the IFAC Technical Committees on Robust Control (since 2003) and Aerospace (since 2005). He has been a regular member of the panel of reviewers of the AMS Mathematical Reviews (since 1999) and *Zentralblatt MATH* (since 2000). Didier Henrion's research interests include numerical algorithms for polynomial matrices, convex optimization over linear matrix inequalities (LMI), with applications in systems control engineering.