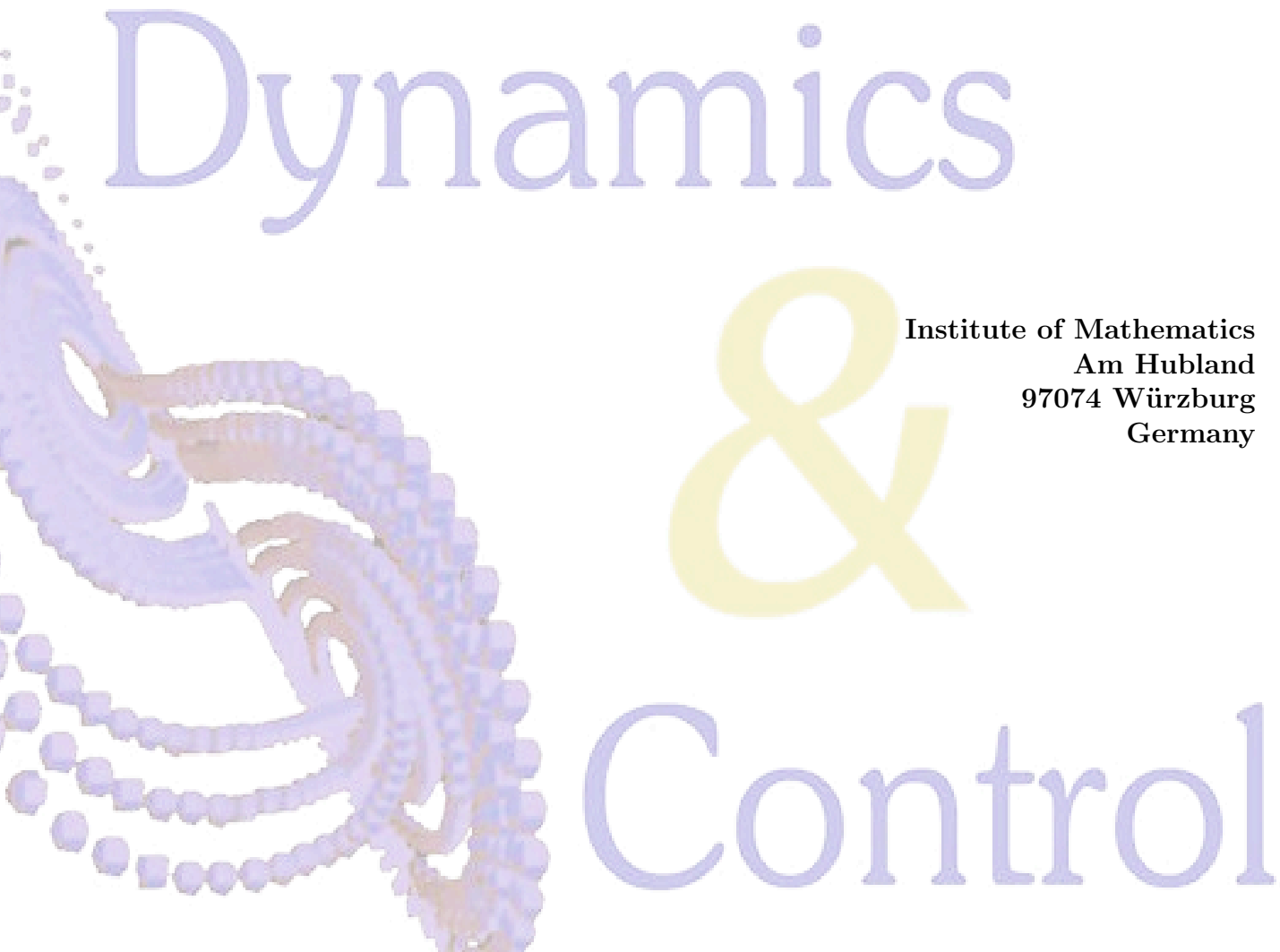
RESEARCH REPORT 2009

Dynamical Systems and Control Theory

Chair: Prof. Dr. Uwe Helmke
Institute of Mathematics
University of Würzburg



Institute of Mathematics
Am Hubland
97074 Würzburg
Germany

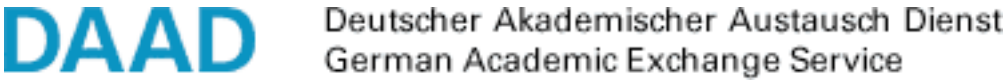
Contact:

Institut für Mathematik
Lehrstuhl für Mathematik II
Universität Würzburg Am Hubland
97074 Würzburg
Germany

phone	: +49 (0)931 31-85004
fax	: +49 (0)931 31-84611
email	: l-math2@mathematik.uni-wuerzburg.de
http	: www2.mathematik.uni-wuerzburg.de

Research Sponsors:

DFG SPP-1305



Interdisziplinäres Zentrum für Klinische Forschung der Universität Würzburg

Contents

1 Introduction

This report accounts for the research activities within the research group "Dynamical Systems and Control Theory" at the Institute of Mathematics, University of Würzburg, Germany, during the year 2009. The research group has long term research record in the areas of mathematical systems and control theory, especially in the following main directions

- Stability theory and analysis of dynamical systems,
- Algebraic and geometric methods for system theory and nonlinear control,
- Optimization on manifolds.

Current research activities focus mainly on the areas of

- Networked Dynamical Systems,
- Control of Quantum Systems,
- Algorithmic Data Processing and Control.

The main objective of our research is to promote mathematical systems and control theory as an efficient tool to comprehensively study and tackle complex problems which increasingly emerge in diverse areas of science and engineering.

In the year 2009, the research group "Dynamical Systems and Control Theory" consisted of 2 professors, 2 senior and 4 junior researchers, as well as 6 PhD students. The group enjoys many international collaborations with partners from other research institutes, universities and industries. The main sources of research funding which enables these collaborations are the German Research Council (DFG), the Federal Ministry of Education and Research (BMBF), the Bavarian State Ministry of Science, Research and Arts (STMWFK), the Volkswagen Foundation and the Interdisciplinary Center of Clinical Research (IZKF) University of Würzburg. Our fund raising activities are expected to continue in the future and further new research projects are being proposed to increase the capacity of the group in the sense that new research directions and applications will be explored and new members of researchers and PhD students will be recruited.

A new development at the Institute for Mathematics is the foundation of the "Center of Computational Mathematics and Systems Research (CMSR)", which aims to harness the expertise of several research groups and bridge towards new application fields. Also, new links with the Fraunhofer Institute of Industrial Mathematics (ITWM) Kaiserslautern are currently being established and will lead to new collaborations with other scientists and engineers.

1.1 Research Group Members

Professors:

Prof. Dr. Uwe Helmke, Prof. Dr. Fabian Wirth

Senior Researchers:

PD Dr. Knut Hüper, Dr. Gunther Dirr

Researchers/Postdocs:

Dr. Anna von Heusinger, Dr. Jens Jordan,
Dr. Martin Kleinsteuber, Dr. Christian Lageman

PhD Students:

Oana Curtef, Sven Herzberg, Indra Kurniawan,
Rudolf Sailer, Michael Schönlein, Martin Schröter

Master/Diploma Students:

Marco Freibert, Roman Geiselhart, Arieh Schlote,
Martin Sonntag, Andreas Staab

1.2 Research Areas

Uwe Helmke

Linear and nonlinear systems theory; Model reduction; Algebraic systems theory; Linear algebra; Differential geometric methods; Tracking and estimation for signal processing and control.

Fabian Wirth

Robust stability for nonlinear and time-varying dynamical systems; Spectral theory for linear time-varying systems; Networked Control Systems; Stability of Queueing Systems; Dynamics of Communication Protocols.

Knut Hüper

Numerical optimization methods on manifolds; Optimization problems in data and signal processing, robotics, computer vision; Differential geometric methods for data analysis and signal processing.

Gunther Dirr

Nonlinear control theory with main focus on invariant control systems on Lie groups and homogeneous spaces; Bilinear control systems on matrix Lie groups and applications to quantum control; Riemannian optimization in quantum computing and tensor approximation.

Anna von Heusinger

Numerical methods for generalized Nash-equilibrium problems; Distributed optimization algorithms for networked control systems.

Jens Jordan

Observation and control of networked systems; Dynamics and geometry of iterative algorithms; Discrete-time control systems on manifolds and Lie groups.

Martin Kleinsteuber

Numerical linear algebra and applications; Algorithms for data and signal processing; Differential geometric methods for optimizations; Data analysis for learning machine and computer vision.

Christian Lageman

Networked control systems; Nonlinear control systems; Observer theory and construction; Optimization on manifolds; Estimation problems on manifolds.

Oana Curtef

Numerical optimization on Riemannian manifolds; Singular value decomposition (SVD) of tensors; Subspace clustering.

Sven Herzberg

Optimization on manifolds; Statistics on manifolds related to image processing and computer vision.

Indra Kurniawan

Dynamics and control of open quantum systems; Bilinear control systems on matrix Lie-groups; Stochastic master equations; Quantum filtering equations and robust approximation; Parameter estimation of quantum systems.

Rudolf Sailer

Control over digital communication channels; Networked control systems; Control with limited information.

Michael Schönlein

Stability of multiclass queueing networks; Stability and robustness of fluid network models; Modelling of logistics networks.

Martin Schröter

Optimization on manifolds including image registration and data compression; Stochastic optimization methods on manifolds.

2 Overview of Main Research Activities

2.1 Networked Dynamical Systems

In this research area, we concentrate on the analysis of the dynamical properties and the design of large-scale systems which consist of many interconnected subsystems. In particular, we investigate the stability of large-scale systems and develop constructive methods of deriving Lyapunov functions. In a second direction, the problems of decentralized control as well as decentralized state estimation are investigated. In these areas, a delicate and interesting interplay of diverse methods is required in order to describe the characteristics of the coupling structure. Relevant techniques come from linear and nonlinear systems theory, from the theory of dynamical systems, involving graph theory and the theory of positive systems. Furthermore, methods from algebraic systems theory and geometric control theory play an important role and find many applications here.

One of our projects, which is supported by the German Research Council (DFG) Priority Program 1305, is the investigation of state estimation, filtering and control of networked dynamical systems over digital communication channels. In general, such channels suffer from fundamental physical limitations which imply hard constraints on the amount of transferable digital data as well as time-varying delays and possible package loss. In this case, conventional approaches from control theory can no longer be directly applied, as it is frequently assumed that all required data transfers are unrestricted and available at any time. Therefore novel approaches will have to be proposed in order to cope with these communication constraints.

A closely related aspect is the modelling of the dynamics of digital data channels. The interplay of these dynamics with that of control systems is an important feature of networked control systems. One of the aspects of our current research is to develop new variants of Transmission Control Protocols (TCP), which is one of the standard communication protocols for data transfer in internet, as well as communication protocols which are designed to support control schemes.

Another application area of networked systems under investigation are large-scale logistics networks and their dynamic behaviour. In the future, the research area of *quantum networks* poses an interesting challenge for system and control theory.

Current Funding

- Volkswagen Foundation Research Project, *"Stability, Robustness and Approximation of Dynamic Large-Scale Networks - Theory and Applications in Logistics Networks".*

- DFG - Priority Program 1305, *"Control Theory of Digitally Networked Dynamical Systems".*
  Project A: Stability and Stabilization of Large Digital Networks.
  Project B: Observation and Control of Heterogeneous Dynamical Systems.

Cooperation Partners

- Chair of Computer Science VII: Robotics and Telematics, University of Würzburg.
- Bremen Institute of Production and Logistics (BIBA), University of Bremen.
- Center of Technomathematics, University of Bremen.
- Hamilton Institute, NUI Maynooth, Ireland.
- Chair of Applied Mathematics, University of Bayreuth.
- Chair of Applied Analysis and Numerics, University of Augsburg.

2.2 Control of Quantum Systems

One of our research interests lies in the emerging, interdisciplinary area of quantum control, i.e. in controlling and observing quantum mechanical systems, e.g. finite dimensional spin systems.

In quantum processes, one distinguishes between so-called *closed quantum systems*, which are considered as isolated systems and thus having no interaction with the environment, and *open quantum systems*, which allow dissipation and relaxation arising from interaction with the environment. While the time evolution of closed quantum systems is described by one-parameter *groups* of unitary operators, the dynamics of open systems is modelled by one-parameter *semigroups* of completely positive operators. Including controls to the associated equations of motion (*Liouville-von Neumann* and *Lindblad-Kossakowski*) leads in both cases to bilinear control systems.

Our group is primarily focusing on fundamental control-theoretic topics such as controllability and reachability. For closed quantum systems, these subjects have been comprehensively investigated. In particular, controllability enjoys a rather simple necessary and sufficient characterization. This is due to the fact that the involved Lie groups are unitary and therefore compact. For open systems, in contrast, numerous reachability questions are still open research problems. Here, the intricate semigroup structure of the underlying Lindblad-Kossakowski master equation requires advanced nonlinear control methods, Lie group theory and model reduction techniques. Beyond that, we are interested in the development of novel approaches to optimal control on Lie groups.

We expect that new results in the field of quantum control will support technical innovations as well as important theoretical foundations in many areas such as quantum imaging, computing and communication. A further research direction of our group aims at these new branches of quantum theory. In particular, we design numerical algorithms to efficiently compute entanglement measures and work on generalizations of the Solovay-Kitaev Theorem. Here, again, methods from Lie group theory play the essential role for analysing the global structure and behaviour of these algorithms.

In a close collaboration with the research focus "Networked Dynamical Systems", we will start to investigate the areas of quantum graphs and quantum networks.

Progress in the field of parameter identification of quantum mechanical systems establishes another crosslink to our research focus "Algorithmic Data Processing and Control".

Current Funding

- Elite Network of Bavaria (ENB) of the Bavarian State Ministry of Science, Research and Arts, under the framework of International Doctorate Program in Engineering and Computer Science: *"Identification, Optimization and Control with Applications in Modern Technologies"*.

Cooperation Partners

- Chair of Theoretical Physics I, University of Würzburg.
- Department of Organic Chemistry, Technical University of Münich.

  In collaboration with the other International Doctorate Program of the Elite Network of Bavaria (ENB): *"Quantum Computing, Control and Communications (QCCC)"*.
- Faculty of Engineering and Information Technology, Australian National University.

2.3 Algorithmic Data Processing and Control

In the area of digital signal and image data processing, and also in control engineering, it is a common problem that the data of the problem under consideration satisfy an intricate geometric constraint. Recently, the related research area of data analysis on manifolds has gained considerable momentum, which increasingly influences the algorithmic development for applications in control engineering and sensor technology. The geometrical analysis of huge data sets is also closely related to the modern development of machine learning, for instance compressed sensing techniques. This approach makes data transfer beyond the Shannon-Nyquist limit feasible.

In the field of computer vision, the problem of 3D-structural analysis from digital camera data leads to a complicated nonlinear estimation problem of trifocal tensors. In medical signal processing, nonlinear image registration is an important tool for the implementation of imaging methods in practical radiology. A particular challenge arises when the comparative representations of data originate from different acquisition techniques e.g. X-ray radiation, microwave, laser or ultrasound technique. Often in this case, relevant geometrical constraints are not appropriately taken into account. An attempt of resolving this issue uses novel mathematical methods e.g. based on kernel functions, spline approximations or wavelet- and Radon-transformations.

A project in cooperation with the Fraunhofer Institute of Industrial Mathematics will focus on algorithmical aspects, especially on their diverse possible application areas originating from biology, medicine and sensor technology. This project, in close collaboration with the users, aims to offer efficient methods. In the framework

of industrial projects as well as participations on individual or joint research projects from BMBF and DFG, efficient methods for geometrical data analysis, sensor data fusion, model reduction and data compression, as well as image data reconstruction are investigated. Mathematically speaking, all these questions reduce to the task of finding algorithmic solutions of nonlinear estimation problems on manifolds. In this area the research group has been active in long term collaborative projects investigating NMR spectroscopy, quantum control, computer vision and robotics.

The research focus "Algorithmic Data Processing and Control" of our group thus splits into the following three major sub-areas.

- Data reduction and data analysis:

  Development of recursive and real-time methods for analysis and parameter reduction of data sets, also for time-varying systems. The techniques used are, for example, applied harmonic analysis and modern techniques from machine learning and compressed sensing.

- Model reduction and system identification:

  Development of methods for model reduction of parameter-dependent linear systems. In this area, interesting crosslinks between computer algebraic methods and system theoretic techniques emerge.

- Numerical methods in robotics and sensoric:

  Development of stable and robust methods for automatic real-time registration problems. This includes e.g. registration problems in medical imaging data, position and pose estimation, tracking from camera data, as well as optimal motion planning and position control in robotics.

Current Funding

- Interdisciplinary Center for Clinical Research (IZKF), University of Würzburg, *"Organ Motion Tracking: Identification of Position and Shape of Anatomical Structures"*.

- Federal Ministry of Education and Research (BMBF), FHprofUnd 2007: Cooperation Program between Universities of Applied Science and companies, *"Development and Implementation of Novel Mathematical Algorithms for Identification and Control of Technical Systems"*.

Cooperation Partners

- Department of Radiation Oncology, University of Würzburg, Research Group Precision Radiotherapy.

- Fraunhofer Institute of Industrial Mathematics (ITWM), Kaiserslautern.

- Chair of Signal Processing, Technical University of Münich.

- Chair of Computer Science VII: Robotics and Telematics, University of Würzburg.

- Department of Mathematics, Ben-Gurion University of the Negev, Israel.
- Research School of Information Sciences and Engineering (RSISE), Australian National University, Canberra, Australia.

3 Research Activities

3.1 Research Projects and Collaborations

1. Volkswagen Foundation, *"Stability, Robustness and Approximation of Dynamic Large-Scale Networks - Theory and Applications in Logistics Networks"*.

   Project Leaders: F. Wirth, Dr. D. Dashkovskiy, Prof. Dr. B. Scholz-Reiter.

   PhD Student: M. Schönlein.

   Period: 11.2007–10.2010.

2. DFG - Priority Program 1305, *"Control Theory of Digitally Networked Dynamical Systems"*.

   Project A: Stability and Stabilization of Large Digital Networks.

   Project Leader: F. Wirth.

   PhD Student: R. Sailer.

   Period: 01.2008–12.2010.

   Project B: Observation and Control of Heterogeneous Dynamical Systems.

   Project Leaders: U. Helmke, Prof. Dr. K. Schilling.

   Postdocs: J. Jordan, A. von Heusinger.

   Period: 10.2007–09.2010.

3. Interdisciplinary Center for Clinical Research (IZKF), University of Würzburg, *"Organ Motion Tracking: Identification of Position and Shape of Anatomical Structures"*.

   Project Leaders: U. Helmke, PD. Dr. O. Sauer.

   PhD Student: M. Schröter.

   Period: 04.2007–12.2009.

4. Federal Ministry of Education and Research (BMBF), FHprofUnd 2007: Cooperation Program between Universities of Applied Science and Industries, *"Development and Implementation of Novel Mathematical Algorithms for Identification and Control of Technical Systems"*.

   Project Leaders: U. Helmke, Prof. Dr. K-H. Spindler.

   PhD Students: S. Herzberg, O. Curtef.

   Period: 06.2007–05.2010.

5. DAAD PPP Spain: *"Robust Positive Observation"*, Collaboration between University of Würzburg and Dpto. Ingenieria de Sistemas y Automatica Universidad de Valladolid, 47005 Valladolid, Spain.

   Researchers Uni Würzburg: U. Helmke, F. Wirth, J. Jordan and M. Schönlein.

   Researchers Uni Valladolid: Prof. Dr. F. Tadeo, Dr. M. Ait Rami and M. Bolajraf.

   Period: 2008–2010.

6. Elite Network of Bavaria (ENB), International Doctorate Program in Engineering and Computer Sciences: *"Identification, Optimization and Control with Applications in Modern Technologies"*, University of Erlangen-Nürnberg, University of Bayreuth and University of Würzburg.

   Project Leaders: U. Helmke, G. Dirr.

   PhD Student: I. Kurniawan.

   Period: 2006–2010.

3.2 Research Workshops and Seminars in Würzburg

1. Workshop on Observer Theory, Meeting of the DFG Priority Programme 1305: Control Theory of Digitally Networked Dynamical Systems, March 2-3, 2009.

   Organized by U. Helmke and J. Jordan.

2. Joint Interdisciplinary Seminar of the International Doctorate Programs of the Elite Network of Bavaria (ENB): *Identification, Optimization and Control with Applications in Modern Technologies, Quantum Control, Computing and Communications (QCCC) and TopMath.*

   Winter and Summer Semester 2009.

   Organized by U, Helmke, F. Wirth, and Prof. Dr. L. Grüne (Uni Bayreuth).

3.3 Activities of Group Members

Prof. Dr. Uwe Helmke

- "A celebration of the field of systems and control theory", An international symposium to celebrate the 60th birthdays of C. I. Byrnes and A. Lindquist, Stockholm, Sweden, September 9-11, 2009.

  Invited Talk: Decidability criteria for unimodular equivalence of polynomial matrices.

- Co-Organization of the workshop "Control Theory: On the Way to new Application Fields", Mathematisches Forschungsinstitut Oberwolfach, February, 22-28, 2009.

- Research Visit at Department of Mathematics, Ben Gurion University of the Negev, Beer Sheva, Israel, September 2009 (host: Prof. Dr. P. A. Fuhrmann).
- Associate Editor: SIAM J. Control and Optimization; Systems and Control Letters; Mathematics of Control, Signals and Systems.
- Dean of the Faculty of Mathematics and Computer Science, University of Würzburg
- Vice Dean of the Graduate School Science and Technology, University of Würzburg.
- Consulting: Bosch Rexroth; Fraunhofer Institute ITWM, Kaiserslautern.
- IEEE Fellow: Award for Contributions to Geometric Theory, Estimation and Tracking.

Fabian Wirth

- Co-Organization of Elgersburg School on Mathematical Systems Theory: "Model Reduction - Theory and Numerics" and "Optimal Control of Partial Differential Equations", with Achim Ilchmann (TU Ilmenau) and Timo Reis (TU Berlin).

  Elgersburg, Germany, March 8-13, 2009.
- Lecturer at HYCON-EECI Graduate School on Control, Course "Mathematical Modelling of Communication Protocols", Supelec, Gif-sur-Yvette, France, March 2-6, 2009.
- Research Visit at Hamilton Institute, NUI Maynooth, Ireland, July 27-31, 2009 (host: Dr. O. Mason).
- Associate Editor: SIAM J. Control and Optimization; Systems and Control Letters.
- Participation in Workshops
  - "Control Theory: On the Way to new Application Fields", Mathematisches Forschungsinstitut Oberwolfach, February 22-28, 2009.

    Contributed Talk: "Lyapunov functions for ISS networks".
  - Workshop on Information and Control, Augsburg, Germany, February 18-19, 2009.
  - Review Colloqium, DFG SPP-1305, Bochum, Germany, August 7-9, 2009.
  - Status Symposium Frontiers in Network Science: Advances and Applications, Berlin, Germany, September 28-30, 2009.

Knut Hüper

- Organization of Special Session within IEEE/SP 15th Workshop on Statistical Signal Processing (IEEE/SSP2009), "Recent Advances in Geometric Optimization and Statistical Signal Processing", Cardiff, UK, August 31–September 3, 2009.

Gunther Dirr

- Participation in Workshop "Control Theory: On the Way to new Application Fields", Mathematisches Forschungsinstitut Oberwolfach, February 22-28, 2009.

Jens Jordan

- Organization of Workshop on Observer Theory, University of Würzburg, March 2-3 2009.

  Contributed Talk: "Perspective observability".

- Research Visit and Meeting of the DAAD Project, Dpto. Ingenieria de Sistemas y Automatica, Universidad de Valladolid, Spain, December 1-8, 2009 (host: Dr. Mustapha Ait Rami).

  Talk: "Perspective observability via ω-limit sets".

Christian Lageman

- Contributed Talks:
  - "Algorithms for nonsmooth optimization on manifolds", 28th Benelux Meeting on Systems and Control, Spa, Belgium, March 16-18, 2009.
  - "Convergence of Gradient-Type Observers for Invariant Systems on SO(n)", SIAM Conference on Control and its Applications, Denver, USA, July 6-8, 2009.
  - "Gradient-like observers on semidirect products", European Control Conference, Budapest, Hungary, August 23-26, 2009.
  - "Observers for systems with invariant outputs", European Control Conference, Budapest, Hungary, August 23-26, 2009.

Michael Schönlein

- Contributed Talks:
  - "Some Remarks on Stability and Robustness of Production Networks Based on Fluid Models", International Conference on Dynamics in Logistics, Bremen, Germany, August 17-21, 2009.
  - "Model Reduction and Stability of Large-Scale Logistics Networks", Status Symposium Frontiers in Network Science: Advances and Applications, Berlin, Germany, September 28-30, 2009.

- Research Visit at Dpto. Ingenieria de Sistemas y Automatica, Universidad de Valladolid, Spain, December 1-21, 2009 (host: Dr. Mustapha Ait Rami).

  Talk: "Stability of fluid network models and Lyapunov functions".

- Participation in Graduate Schools:

  – "Model Reduction - Theory and Numerics" (by T. Antoulas) and "Optimal Control of Partial Differential Equations" (by F. Tröltzsch), Graduate Summer School on Mathematical Systems Theory, Elgersburg, Germany, March 8-13, 2009.

  – "The Use of Poisson Processes in Modelling and Nonlinear Control" (by R. Brockett), HYCON-EECI Graduate School on Control, Supelec, Paris, France, April 27-31, 2009.

Rudolf Sailer

- Contributed Talk: "Stabilization of non-linear systems with delayed data-rate limited feedback", European Control Conference, Budapest, Hungary, August 23-26, 2009.

- Participation in Graduate Schools and Workshops:

  – "Model Reduction - Theory and Numerics" (by T. Antoulas) and "Optimal Control of Partial Differential Equations" (by F. Tröltzsch), Graduate Summer School on Mathematical Systems Theory, Elgersburg, Germany, March 8-13, 2009.

  – "Stabilization of Nonlinear Dynamical Systems" (by L. Praly) and "Mathematical Modeling of Communication Protocols" (by F. Wirth), HYCON-EECI Graduate School on Control, Supélec, Gif-sur-Yvette, France, January 26-30, 2009 and March 2-6, 2009.

  – Workshop on Information and Control, Augsburg, Germany, February 18-19, 2009.

  – Workshop on Control with Limited Information, Bochum, Germany, March 19-20, 2009.

  – Workshop NESCOC and NETCOC: "Network Induced Constraints in Control, Recent Trends in Networked Systems and Cooperative Control", Stuttgart, Germany, September 28-29, 2009.

  – Review Colloqium, DFG SPP-1305, Bochum, Germany, August 7-9, 2009.
  Talk: "Stability and stabilization of large-scale networks".

Indra Kurniawan

- Contributed Talk: "Controllability aspects of open quantum systems: Lie theoretical approach".

  Graduate Summer School *Identification, Optimization and Control with Applications in Modern Technologies* and Joint Meeting with *Bavarian Graduate*

School of Computational Engineering and *Top Math* of the Elite Network of Bavaria (ENB), Freising, Germany, July 27-29, 2009.

- Participation in Graduate Schools:
  - "Identification, Optimization and Control with Applications in Modern Technologies", Winter School, Thurnau, Germany, March 4-6, 2009.
  - "Networked Control Systems" (by R. Murray and V.Gupta), HYCON-EECI Graduate School on Control, Supélec, Gif-sur-Yvette, France, March 16-20, 2009.

Martin Schröter

- Contributed Talk: "Quasi-Newton algorithms for medical image registration".

  World Congress on Medical Physics and Biomedical Engineering, Munich, Germany, September 7-12, 2009.

3.4 Completed Diploma Theses

- *Zur totalen Krümmung geschlossener Kurven*, Andreas Staab, 2009.

  Supervisor: U. Helmke.

- *The Solovay-Kitaev Theorem for Compact Lie Groups*, Marco Freibert, January 2009.

  Supervisor: U. Helmke.

3.5 Diploma Theses in Progress

- *Stability of TCP models*, Arieh Schlote, since 01.01.2009.

  Supervisor: F. Wirth.

- *Homotopy algorithms and the numerical construction of ISS Lyapunov functions*, Roman Geiselhart, since 01.04.2009.

  Supervisor: F. Wirth.

- *Topics on Stochastic Matrices.* Martin Sonntag, since 2009.

  Supervisor: U. Helmke.

3.6 Completed PhD Theses

- *Controllability Aspects of the Lindblad-Kossakowski Master Equation : A Lie Theoretical Approach*, Indra Kurniawan, December 2009.

  Supervisor: U. Helmke.

3.7 PhD Theses in Progress

- *Stability and robustness of queueing networks: A Lyapunov approach across disciplines*, Michael Schönlein, since 01.11.2007.

  Supervisor: F. Wirth.

- *Stability and stabilization of large scale digital networks*, Rudolf Sailer, since 01.01.2008.

  Supervisor: F. Wirth.

- *Newton methods for medical image registration*, Martin Schröter, since 01.04.2007.

  Supervisor: U. Helmke.

- *Numerical algorithms for the optimization of Rayleigh-quotient like functions on Riemannian manifolds*, Oana Curtef, since 01.11.2006.

  Supervisor: U. Helmke.

- *Time-optimal control of the bi-steerable robot: A case study in optimal control of non-holonomic systems*, Markus Mauder (external PhD student), since 23.06.2004.

  Supervisor: U. Helmke.

3.8 External Reports

F. Wirth

- Dr. Michael Karow, *Structured pseudospectra, μ-values and eigenvalue condition numbers*, Habilitation thesis, Technical University of Berlin, June 2009.

- Dr. Sergey Dashkovskiy, *Modelling and analysis of complex systems and processes*, Habilitation thesis, University of Bremen, October 2009.

3.9 Visitors

- Prof. Dr. P. A. Fuhrmann, March 2009
  Ben-Gurion University of Negev, Beer Sheva, Israel.

- Prof. Dr. G. Nair, March 2009
  University of Melbourne, Australia.

- Prof. Dr. K. Spindler, April 2009
  FH Wiesbaden, Germany.

- Dr. M. Margaliot, April 2009
  Tel Aviv University, Israel.

- Prof. Dr. B. Ghosh, May 2009
  Texas Tech University, Lubbock, Texas, USA.

- Prof. Dr. R. Middleton, May 2009
  Hamilton Institute, NUI Maynooth, Ireland.
- Prof. Dr. C. Byrnes, April 2009 - July 2009
  Washington University in St. Louis, USA.
- Prof. Dr. F. S. Leite, June 2009
  University of Coimbra, Portugal.
- M. Bolajraf, June 2009
  Universidad de Valladolid, Spain.
- Prof. Dr. F. Tadeo, June 2009
  Universidad de Valladolid, Spain.
- Dr. S. Trenn, July 2009
  TU Ilmenau, Germany.
- Prof. Dr. A. Lindquist, July 2009
  KTH Stockholm, Sweden.
- Dr. M. Ait Rami, October 2009
  Universidad de Valladolid, Spain.
- Dr. Ł. Budzisz, October 2009
  Hamilton Institute, NUI Maynooth, Ireland.

4 Publications

4.1 Journal Papers

1. G. Dirr, U. Helmke and J. Jordan, Control and Observation of the Matrix Riccati Differential Equation, in *Emergent Problems in Nonlinear Systems and Control*, LN in Control and Information Sciences, B. Ghosh et al. (Eds.), Springer, pp. 169-184, 2009.
2. G. Dirr, U. Helmke, I. Kurniawan and T. Schulte-Herbrüggen, Lie-semigroup Structures for Reachability and Control of Open Quantum Systems: Kossakowski-Lindbald Generators form Lie Wedge to Markovian Channels, *Reports on Math. Physics* 64:93-121, 2009.
3. P. Fuhrmann and U. Helmke, Unimodular equivalence of polynomial matrices. *Byrnes-Lindquist Festschrift*, Springer-Verlag, 2009.
4. U. Helmke, Global convergence of nonlinear cascade flows with Morse-Bott zero dynamics. *Systems and Control Letters*, 58(6):389-468, 2009.
5. M. Kleinsteuber, A sort-Jacobi algorithm for semisimple Lie-algebras, *Linear Algebra and its Applications*, 430(1):155-173, 2009.

6. H. Shen, K. Hüper and M. Kleinsteuber, On FastICA Algorithms and Some Generalizations, *Lecture Notes in Electrical Engineering: Numerical Linear Algebra in Signals, Systems and Control*, Springer-Verlag, 2009.

7. K. Wulff, F. Wirth and R. Shorten, A control design method for a class of SISO switched linear systems, *Automatica* 45(11):2592-2596, 2009.

Submissions

1. S. Dashkovskiy, M. Kosmykov, and F. Wirth, A small gain condition for interconnections of ISS systems with mixed ISS characterizations, *IEEE Trans. Aut. Control*, August 2009.

2. S. Dashkovskiy, B.S. Rüffer, and F.R. Wirth, Small gain theorems for large scale systems and construction of ISS Lyapunov functions, *SIAM J. Control Optim.*, August 2009.

3. S. Dashkovskiy, H. Ito, and F. Wirth, On a small gain theorem for ISS networks in dissipative Lyapunov form, *European J. Control*, August 2009.

4. J. Jordan and U. Helmke, Control and stabilization of linear equation solvers, Springer Verlag Lecture Notes Series in Control and Information Sciences, Springer, 2009.

5. B.S. Rüffer, R. Sailer, and F.R. Wirth, Comments on "A multichannel IOS Small Gain Theorem for Systems With Multiple Time-Varying Communication Delays", *IEEE Trans. Aut. Control*, March 2009.

6. S. Said, C. Lageman, N. Le Bihan and J.H. Manton, Decompounding on compact Lie groups, *IEEE Trans. Information Theory*, 2009.

7. T. Schulte-Herbrüggen, S. Glaser, G. Dirr and U. Helmke, Gradient Flows for Optimisation and Quantum Control: Foundations and Applications, *Reviews in Math. Physics*, 2009.

4.2 Conference Papers

1. F. Camilli, L. Grüne, and F. Wirth, *Domains of attraction of interconnected systems: A Zubov method approach*, Proc. European Control Conference, ECC 2009, Budapest, Hungary, July 2009, pp. 91-96.

2. S. Dashkovskiy, M. Kosmykov, and F. Wirth, *A small gain condition for interconnections of ISS systems with mixed ISS characterizations*, Proc. European Control Conference, ECC 2009, Budapest, Hungary, July 2009, pp. 1083-1088.

3. S. Dashkovskiy, H. Ito, and F. Wirth, *On a small gain theorem for ISS networks in dissipative Lyapunov form*, Proc. European Control Conference, ECC 2009, Budapest, Hungary, July 2009, pp. 1077-1082.

4. G. Dirr, U. Helmke and J. Jordan, *Global observability of real analytic systems*, Proc. European Control Conference, ECC 2009, Budapest, Hungary, July 2009, pp. 4582-4586.

5. T. Hamel, R. Mahony, J. Trumpf and C. Lageman, *Nonlinear attitude observers on SO(3) for complementary and reciprocal measurements: a theoretical study*, Proc. 48th IEEE Conference on Decision and Control, CDC 2009, Shanghai, China, December 2009, pp. 6407-6412.

6. H. Ito, S. Dashkovskiy, and F. Wirth, *On a small gain theorem for networks of iISS systems*, Proc. 48th IEEE Conference on Decision and Control, CDC 2009, Shanghai, China, December 2009, pp. 4210-4215.

7. C. Lageman, A. Sarlette and R. Sepulchre, *Synchronization with partial state feedback on SO(n)*, Proc. 48th IEEE Conference on Decision and Control, CDC 2009, Shanghai, China, December 2009, pp. 1696-1701.

8. C. Lageman, J. Trumpf and R. Mahony, *Observers for systems with invariant outputs*, Proc. European Control Conference, ECC 2009, Budapest, Hungary, July 2009, pp. 4587-4592.

9. C. Lageman, J. Trumpf and R. Mahony, *Gradient-like observers on semidirect products*, Proc. European Control Conference, ECC 2009, Budapest, Hungary, July 2009, pp. 3973 - 3977.

10. S. Said, N. Le Bihan, C. Lageman and J.H. Manton, *Nonparametric estimation for compound Poisson processes on compact Lie groups*, Proceedings of the IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP) 2009, pp. 3409 - 3412.

11. R. Sailer and F. Wirth, *Stabilization of nonlinear systems with delayed data-rate-limited feedback*, Proc. European Control Conference, ECC 2009, Budapest, Hungary, July 2009, pp. 1734-1739.

12. B. Scholz-Reiter, F. Wirth, S. Dashkovskiy, M. Schönlein, T. Makuschewitz, and M. Kosmykov: *Some remarks on stability and robustness of production networks based on fluid models.* To appear in Proceedings of the 2nd International Conference on Dynamics in Logistics (LDIC), Bremen, Germany, August 17-21, 2009.

13. B. Scholz-Reiter, F. Wirth, S. Dashkovskiy, T. Makuschewitz, M. Kosmykov, and M. Schönlein: *An approach to model reduction of logistic networks based on ranking.* To appear in Proceedings of the 2nd International Conference on Dynamics in Logistics (LDIC), Bremen, Germany, August 17-21, 2009.

14. B. Scholz-Reiter, F. Wirth, S. Dashkovskiy, T. Makuschewitz, M. Kosmykov, and M. Schönlein: *Application of the PageRank algorithm for ranking locations of a production network.* To appear in Proceedings of 42nd CIRP Conference on Manufacturing Systems 2009.

15. M. Schröter and O. Sauer, *Quasi-Newton algorithms for medical image registration*, in Proceedings of the International Federation for Medical and Biological Engineering (IFMBE), Vol. 25(4), World Congress 2009 on Medical Physics and Biomedical Engineering, Munich, Germany, September 2009, pp. 433–436.

16. H. Shen, K. Diepold and K. Hüper, *Geometric Algorithms for the Non-Whitened One-Unit Linear Independent Component Analysis Problem*, Proc. 15th IEEE Workshop on Statistical Signal Processing, SSP 2009, Cardiff, Wales, UK, September 2009, pp. 381–384.

17. H. Shen and K. Hüper, *Block Jacobi-type Methods for Non-Orthogonal Joint Diagonalisation*, Proc. 34th IEEE International Conference on Acoustics, Speech, and Signal Processing, ICASSP 2009, Taipei, Taiwan, April 2009, pp. 3285–3288.