Optimization with Partial Differential Equations 2026

University of Würzburg

September 16 – 18, 2026

Book of Abstracts

Contents

1 Workshop at a Glance

Time	Wednesday	Thursday	Friday
09:00	(Welcome Desk open)	Invited	Invited
10:00	(Welcome Desk open)	Coffee	Coffee
10:30	Opening + Invited + Contributed	Contributed Talks	Contributed Talks
12:30	Lunch	Lunch	Closing
14:00	Invited	Contributed	—
15:00	Coffee	Coffee	
15:30	Contributed Talks	Contributed Talks	
17:00		GAMM meeting	
19:00	Workshop Dinner		

The times here are only a rough indication. More details for each day can be found below.

2 Scientific Programme

2.1 Wednesday, 16.09.2026

Time	Type	Speaker	Title
09:00–10:30	Registration		
10:30–10:45	Opening Remarks		
10:45–11:45	**Invited**	Alberto de Marchi	Numerical Approaches to Regularized Nonlinear Programming
11:45–12:10	Contributed	Bastian Dittrich	A DC-Reformulation for Gradient-L^0-Constrained Problems
12:10–12:35	Contributed	Daniel Walter	Nonconvex regularization in sparse minimization problems
12:35–14:00	*Lunch Break*		
14:00–15:00	**Invited**	Carmen Gräßle	Optimal control perspective on 4D-Var data assimilation: error estimates and reduced order modeling
15:00–15:25	Contributed	Philipp Graser	Numerical Approach to Nonsmooth Optimal Control Problems governed by Nonlinear Elliptic PDE's
15:25–15:55	*Refreshment Break*		
15:55–16:20	Contributed	Constantin Christof	Superlinear Convergence for Semismooth Newton Methods in Vector Lattice Spaces
16:20–16:45	Contributed	Kilian Bernreuther	Sparsity-Promoting Time-Optimal Control of Bilinear Quantum Systems: A Semismooth Newton Approach
19:00	**Conference Dinner**		

2.2 Thursday, 17.09.2026

Time	Type	Speaker	Title
09:00–10:00	**Invited**	Johannes Haubner	Optical flow based optimal control for image registration
10:00–10:30	*Refreshment Break*		
10:30–10:55	Contributed	Gabriel Wittum	Efficiently Solving Nonlinear Time-Dependent Problems from the Geosciences
10:55–11:20	Contributed	Ivan Gallo	A phase-constrained semi-Lagrangian HJB scheme for autoclave cure-cycle simulation
11:20–11:45	Contributed	Jason Seeger	Robust Topology Optimization of Electric Machines using Topological Derivatives
11:45–12:10	Contributed	Anton Schiela	Optimal control of an inextensible sheet
12:10–14:00	*Lunch Break*		
14:00–14:25	Contributed	Christian Lange	Boundary optimal control of a continuity equation using trace renormalization
14:25–14:50	Contributed	Pedro Blöss Braga	Optimal control for renormalized solutions of nonlinear evolution equations
14:50–15:15	Contributed	Stefan Ulbrich	A Sensitivity and Adjoint Calculus for Optimal Control of Discontinuous Solutions of Hyperbolic Systems of Balance Laws
15:15–15:45	*Refreshment Break*		
15:45–16:10	Contributed	Gerd Wachsmuth	How to find the correct function space for second-order optimality conditions?
16:10–16:35	Contributed	Nicolas Borchard	Weak-$\star$ second subderivative of transport distances
17:00	**GAMM Meeting**		

2.3 Friday, 18.09.2026

Time	Type	Speaker	Title
09:00–10:00	**Invited**	Philipp Guth	Output-Feedback Control of Uncertain Linear Systems
10:00–10:30	*Refreshment Break*		
10:30–10:55	Contributed	Roland Herzog	Preconditioned solution of a magnetostatic optimal control problem
10:55–11:20	Contributed	Alimhan Musalatov	Switching Point Optimization for Abstract Parabolic Equations
11:20–11:45	Contributed	Simon Blomeyer	Directional differentiability for the solution map of the bilateral parabolic obstacle problem
11:45–12:10	Contributed	Jan Kimmel	Optimal Control Problems Governed by McKean-Vlasov equations with applications in synchrotrons
12:10–12:30	*Closing Remarks*		

3 Practical Information

Venue

The address of the venue is *Emil-Fischer-Straße 41, 97074 Würzburg*. It is located at the *Campus Hubland Nord*. It can be reached by bus. The nearest bus stops are "Campusbrücke" and "Emil-Fischer-Straße". It can in particular be reached by bus lines 14 (starting at the Main Station) and 10 (starting at Sanderring), but also some other lines are possible. The app for the local public transport can be downloaded (for Android) here: https://play.google.com/store/apps/details?id=com.mdv.wvvgullivr&hl=de.

There are also many parking spots for cars and bikes available.

Registration & WiFi

The registration desk will be open on Wednesday from 9 a.m. on.

The easiest way to connect to WiFi is using *eduroam*. For this you need to have an account provided by your home institution.

Otherwise, you can login in the open *@BayernWLAN*. For this, you then have to confirm the connection in the browser.

Visiting Würzburg

Würzburg is a quite touristic city with many churches and baroque buildings. If you want to extend your stay, you can look for example here for inspiration what to visit: https://www.wuerzburg.de/tourismus/wuerzburg-entdecken. In particular the *Residenz* is a UN World Heritage Site and worth a visit. But you can also enjoy some Würzburg wine on the *Alte Mainbrücke* or take a walk in the inner city.

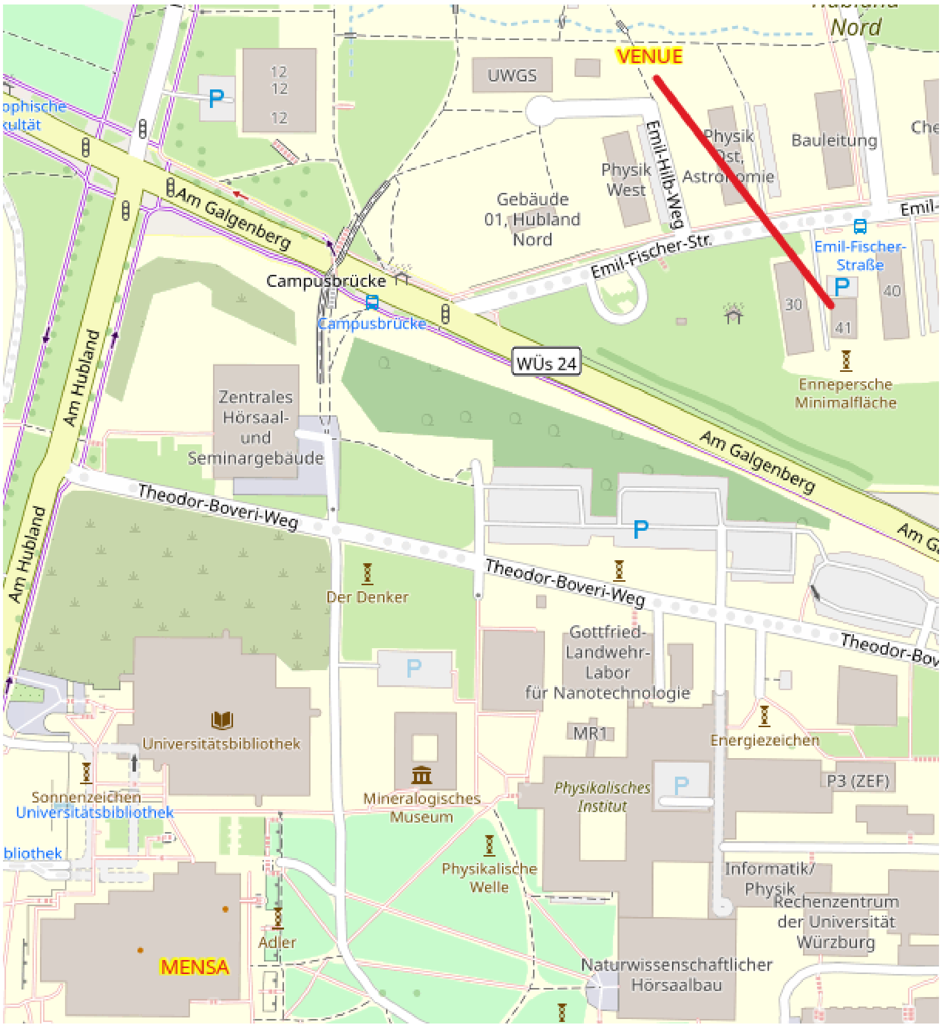

Figure 1: OpenStreeMap view of the venue

Restaurants

There is the "Mensa" nearby the Venue. The lunch is *included in the conference fee*! For this, you only have to show your name tag in the mensa. Otherwise, it is for guest only possible to pay by cash (for coffee, tea etc). The menu can be looked up on this website `https://www.swerk-wue.de/en/wuerzburg/food/canteens-menus/mensa-campus-hubland-sued`.

Conference Dinner

The Conference Dinner will take place in the *Juliusspital*. You can reach it with public transport by going with the tram to *Juliuspromenade* or by bus going to *Barbarossaplatz*. See Figure 2.

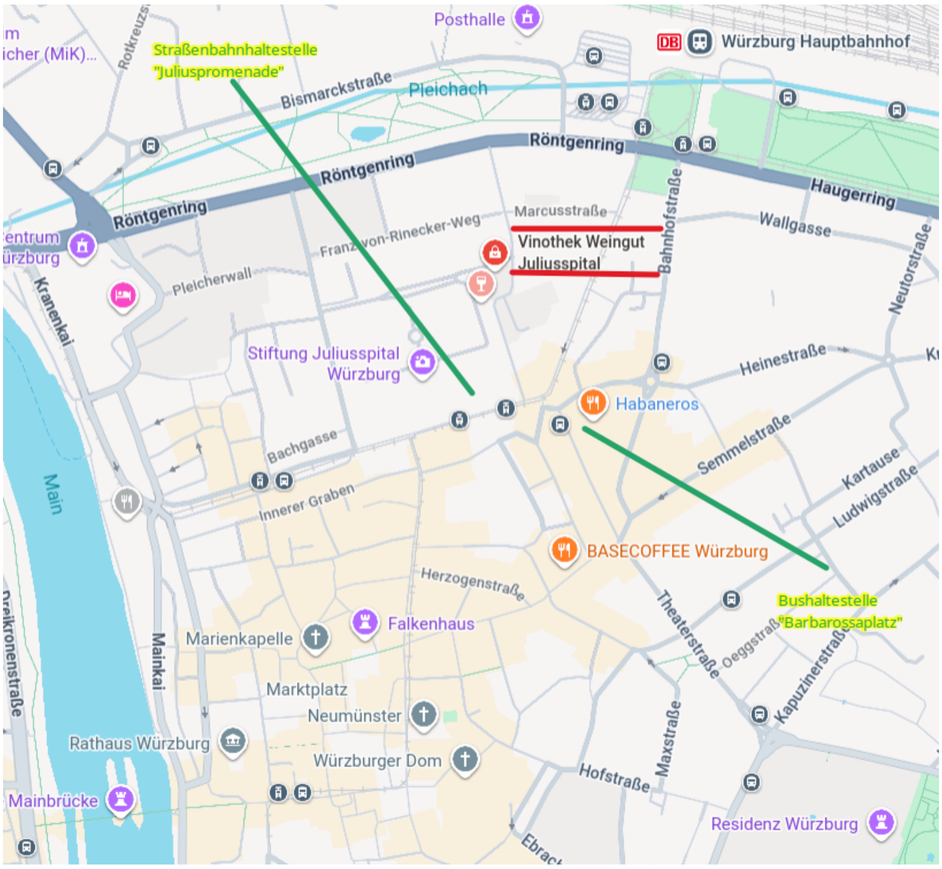

Figure 2: Inner city of Würzburg where also the conference dinner takes place

4 Abstracts of Invited Talks

Numerical Approaches to Regularized Nonlinear Programming

De Marchi Alberto

University of the Bundeswehr Munich
Department of Aerospace Engineering

How can we solve minimization problems with structured objective function (sum of a smooth and a prox-friendly term) and smooth constraints?

Penalty, augmented Lagrangian and barrier schemes have been proposed to tackle this problem class, reducing it to a sequence of structured subproblems that can be handled by proximal-gradient methods.

After reviewing these schemes, this talk introduces a different approach that combines the augmented Lagrangian framework with the Moreau envelope, allowing the use of mature nonlinear programming technology. The resulting method, named Envelopt, comes with appropriate convergence guarantees in the nonconvex setting.

Output-Feedback Control of Uncertain Linear Systems

Philipp Guth

Austrian Academy of Sciences
Johann Radon Institute for Computational and Applied Mathematics Linz

Differential equations with random coefficients are a widely used framework for modeling uncertainty arising from incomplete data, measurement errors, or external disturbances. In optimization and control, such uncertainties can substantially affect system behavior, making robust control a central challenge. This talk focuses on robust feedback control for uncertain linear systems.

- First, the offline synthesis of feedback laws based on sampling and generalized polynomial chaos expansions is discussed.
- Then, a dynamic, data-driven framework that couples feedback control with sequential Bayesian parameter estimation is presented. In this setting, a virtual model evolves alongside the physical system and simultaneously serves as an observer, parameter estimator, and feedback controller. It reconstructs the system state via observer design, generates stabilizing feedback, and updates uncertain model parameters through Bayesian inference using measurements from the controlled dynamics.

Numerical experiments illustrate the effectiveness of the proposed framework and demonstrate robust closed-loop performance in the presence of parameter uncertainty.

Optimal control perspective on 4D-Var data assimilation: error estimates and reduced order modeling

Carmen Gräßle

University of Braunschweig
Carl-Friedrich-Gauß Institut

In this talk, we formulate a four-dimensional variational (4D-Var) data assimilation problem as an optimal control problem in which the initial condition itself serves as the control variable to be estimated. A reformulation of the associated optimality system as an all-at-once system leads to a coupled problem in space-time for which we derive a-posteriori error estimates in regards to time.

Within the data assimilation framework, we investigate the impact of temporal adaptivity on both the discretization scheme and the timing of observations. Since the involved high-fidelity problem can be costly to solve, we study the application of suitable model reduction approaches and analyze the efficiency and accuracy. Numerical examples illustrate the methods.

This is joint work with Jannis Marquardt.

Optical flow based optimal control for image registration

Johannes Haubner

University of Graz
Department of Mathematics and Scientific Computing

Image registration has several applications, amongst others in computer vision and medical imaging. The goal is to align different images, e.g., measured at different times or by different sensors.

By parameterizing the transformations to align the images via velocity fields, we consider image registration as an optimal control problem using an optical flow formulation. More precisely, we aim to solve an optimization problem that is governed by a linear hyperbolic transport equation.

To obtain non-smooth features and ensure bi-Lipschitz continuity of the transformations, we aim for Lipschitz regularity of the velocity fields. We introduce relaxations of the optimization problem involving smoothed maximum and minimum functions and appropriate Orlicz spaces. To derive well-posedness results for the relaxed optimization problems, we revisit and establish new existence and uniqueness results for the linear hyperbolic transport equation.

We further discuss limit considerations with respect to the relaxation parameter and discretization, differentiability, and a numerical implementation of the proposed approach.

5 Abstracts of Contributed Talks

Sparsity-Promoting Time-Optimal Control of Bilinear Quantum Systems: A Semismooth Newton Approach

Kilian Bernreuther

Julius-Maximilians-Universität Würzburg
Institut für Mathematik

Time-optimal quantum control seeks to steer a spin system to a prescribed target in minimal time using bounded control pulses. In this talk, we consider bilinear quantum spin dynamics arising from the Liouville-von Neumann master equation and include an L^1-control cost that promotes sparsity in time. For the numerical treatment of the non-smooth problem, we relax the terminal constraint by a penalty term and introduce an L^2-regularization of the control. We establish convergence of solutions of the regularized problems to solutions of the fixed-endpoint problem as the regularization vanishes and the terminal penalty increases. For a positive sparsity weight, the limiting procedure selects minimum-L^1-norm time-optimal controls. A time-normalized Pontryagin-type characterization leads to a saturation-based switching law. Based on the associated optimality system, we develop a continuation-based semismooth Newton method and obtain local superlinear convergence under a coercivity condition on a generalized Jacobian. Numerical experiments for one- and two-qubit spin systems illustrate the convergence behaviour of the method and show how the sparsity parameter affects the switching structure and the optimal transfer time. This is joint work with Alfio Borzì.

Directional differentiability for the solution map of the bilateral parabolic obstacle problem

Simon Blomeyer

TU Darmstadt
Optimization – Mathematics

We prove that the solution map of the classical bilateral parabolic obstacle problem is directionally differentiable when interpreted as a function between suitable Lebesgue and Sobolev spaces. The proof is based on the differentiability properties of the fixed-point operator for parameter-dependent non-expansive mappings. To our knowledge this is the first contribution on directional differentiability for the parabolic bilateral case. This is joint work with Constantin Christof from TU Darmstadt.

Optimal control for renormalized solutions of nonlinear evolution equations

Pedro Blöss Braga

Friedrich-Alexander Universität Erlangen-Nürnberg (FAU)
Department Mathematik

We establish the existence of optimal controls for a class of nonlinear parabolic evolution equations governed by Leray-Lions type operators with convection terms and pointwise control constraints. The state equation is interpreted in the framework of renormalized solutions, which is essential due to the low regularity and insufficient integrability of the state variable for the classical weak formulation. The proof combines a truncation approach with the direct method of the calculus of variations. For each truncation level, existence of optimal controls is obtained by exploiting stability properties of renormalized solutions. The passage from the truncated problems to the original optimal control problem is then achieved through a Γ-convergence argument and the convergence of the truncations.

Weak-$\star$ second subderivative of transport distances

Nicolas Borchard

BTU Cottbus-Senftenberg / Brandenburgische Technische Universität
Institut für Mathematik – Fachgebiet Optimale Steuerung

In this talk, we consider the minimization of the sum of a smooth functional and a transport term like the famous Wasserstein term. For the derivation of optimality conditions the theory of weak-$\star$ second subderivatives is used. Under some assumptions, we were able to show the equivalence of the positive definiteness of a second-order term and quadratic growth. Further, the exact weak-$\star$ second subderivative is calculated. This talk is based on a joint work with Christian Meyer (Dortmund) and Gerd Wachsmuth (Cottbus).

Superlinear Convergence for Semismooth Newton Methods in Vector Lattice Spaces

Constantin Christof

TU Darmstadt
FB Mathematik, AG Optimierung

We study the convergence of semismooth Newton methods for optimization problems that are formulated in vector lattice Hilbert spaces and involve box-constraints. It is shown that, in such spaces, the validity of a no-gap second-order optimality condition and strict complementarity at a local minimizer are enough to ensure the local q-superlinear convergence of the semismooth Newton algorithm. Our results can be applied, for example, to minimization problems in ordinary and fractional Sobolev spaces with distributed pointwise constraints. The talk is based on joint work with Michael Ulbrich (TUM).

A DC-Reformulation for Gradient-L^0-Constrained Problems

Bastian Dittrich

Julius-Maximilians-Universität Würzburg
Institut für Mathematik

We are interested in sparse optimization problems with convex objective where sparsity is achieved by an explicit L^0-constraint. This non-convex constraint can be equivalently reformulated by the difference of two convex functions, the L^1-norm and the so-called largest-K-norm. A penalty approach renders the resulting problem to be of difference-of-convex (DC) type, which can be adressed using the well-known DC algorithm. In this talk we extend this DC-reformulation approach to problems with L^0-type cardinality constraints on the support of the gradients, i.e., problems where sparsity of the gradient and thus piecewise constant solutions are the target.

A phase-constrained semi-Lagrangian HJB scheme for autoclave cure-cycle simulation and optimization

Ivan Gallo

University of Bologna
Department of Civil, Chemical, Environmental and Materials Engineering

This work studies the optimization of industrial autoclave cure cycles for thermoset composite laminates. The process is described by a reduced thermo-chemical model with three state variables: the degree of cure, the laminate temperature, and the autoclave temperature. The control is the heating or cooling rate of the autoclave. The industrial structure of the cycle is retained by imposing time-dependent constraints corresponding to the usual ramp–dwell–ramp–dwell–cooling sequence. Additional terminal constraints require the prescribed degree of cure to be reached and the autoclave temperature to be low enough for unloading. The resulting finite-horizon optimal-control problem is formulated through a state-constrained Hamilton–Jacobi–Bellman equation. The HJB problem is approximated by a semi-Lagrangian dynamic-programming scheme on a tensor-product grid. Multilinear interpolation is used for off-grid states, with a conservative feasibility rule: a transition is accepted only when all grid nodes involved in the interpolation are feasible. This allows terminal feasibility to be propagated backward through the grid and ensures that every completed feedback trajectory satisfies the prescribed terminal constraints. The numerical implementation also highlights resolution conditions relating the time step, the state grid, and the control discretization. The resulting feedback law is compared with a fixed industrial cure cycle under the same reduced model and cost functional. In the baseline test, the HJB-controlled cycle reduces the objective from 10.648 to 8.237, corresponding to a reduction of 22.6%, while respecting the prescribed phase structure and terminal requirements. Most of this difference is due to smoother heating and cooling rates rather than to a substantial change in the heat-transfer contribution. The results therefore show the potential of constrained HJB feedback for improving an industrial cycle within a prescribed production framework, while remaining limited to the reduced model considered here.

Numerical Approach to Nonsmooth Optimal Control Problems governed by Nonlinear Elliptic PDE's

Philipp Graser

Julius-Maximilians-Universität Würzburg
Institut für Mathematik

In the work presented by Daniel Wachsmuth at the FGS 2024, a method of solving nonsmooth optimal control problems subject to linear elliptic partial differential equations with homogenous Dirichlet boundary conditions was provided. There the functional of interest was of the form

$$J(y,u) \coloneqq \frac{1}{2}||y - y_d||^2_{L^2(\Omega)} + \int_\Omega g(u)\mathrm{d}x,$$

and $g\colon \mathbb{R} \to \overline{\mathbb{R}}$ was assumed to be lower semicontinuous and proper. We will extend this method to semilinear and bilinear elliptic control problems, i.e. with constraints of the form

$$-\Delta y + f(y) = u \text{ in } \Omega, \quad y = 0 \text{ on } \partial\Omega$$

and

$$-\Delta y + uy = j \text{ in } \Omega, \quad y = 0 \text{ on } \partial\Omega.$$

Also we present some promising numerical results.

Optimal Control Problems Governed by McKean-Vlasov Equations with Applications in Synchrotrons

Jan Kimmel

Julius-Maximilians-Universität Würzburg
Institut für Mathematik

We investigate optimal control problems arising in synchrotrons where a stable coherent emissionf frequency should be generated. We model the physical behaviour using a McKean-Vlasov equation and derive a corresponding optimality system for a functional tailored for the specific application. We discuss algorithms to solve the arising equations numerically.

Boundary optimal control of a continuity equation using trace renormalization

Christian Lange

Friedrich-Alexander Universität Erlangen-Nürnberg (FAU)
Mathematik

This talk focuses on the boundary optimal control of a continuity equation. We consider a drift field with very low regularity (specifically, BV-regularity in space), which necessitates the use of renormalized solutions, a technique developed by Ronald DiPerna and Pierre-Louis Lions. This foundational theory has been adapted to a bounded domain by Gianluca Crippa and coworkers using a technique called trace renormalization. I am going to outline the theory for this PDE and present a PDE-constrained optimization problem and a functional-analytic framework concerning the existence of optimal controls and the corresponding optimality criteria.

Switching Point Optimization for Abstract Parabolic Equations

Alimhan Musalatov

Technische Universität Dortmund
Lehrstuhl für Mathematik

This talk is concerned with a switching point optimization problem governed by a semilinear parabolic equation in abstract function spaces. It is shown that the switching-point-to-control mapping is continuously Fréchet-differentiable when considered with values in the dual of Hölder continuous functions in time. By treating the state equation in weak form based on the concept of maximal parabolic regularity, one can then show that the reduced objective is continuously differentiable w.r.t. the switching points, which allows to use gradient-based methods like the proximal gradient method for its minimization. Numerical experiments confirm our theoretical findings, but also illustrate that such a method will in general not be able to solve the problem to global optimality due to the non-convex nature of the switching-point-to-control map. We therefore give a precise characterization of the convex hull of set of feasible switching functions in terms of an extended formulation.

Preconditioned solution of a magnetostatic optimal control problem

Herzog Roland

Heidelberg University
Interdisciplinary Center for Scientific Computing

We consider the preconditioned iterative solution for the optimal control of magnetostatic equations. The proposed method considers a proper regularization of the saddle-point forward system, featuring a positive-definite structure and preserving the divergence-free condition for the state. On the basis of the resulting optimality system, we develop a specific preconditioner with upper and lower bounds for the eigenvalues with mild dependence on the regularization parameter and the mesh size. This property guarantees the desired robustness of the proposed preconditioner in the limit case, which is as well confirmed by our numerical tests.

Optimal control of an inextensible sheet

Anton Schiela

Universität Bayreuth
Mathematisches Institut Lehrstuhl für Angewandte Mathematik

Inextensible sheets can be modelled as variational problems with geomtric constraints, namely that the deformation gradient is an element of the Stiefel manifold of orthogonal 3×2 matrices. The optimal control of such a model has to take this geometric structure into account. In this talk we discuss this problem, including its modelling, formal derivation of optimality conditions, and its numerical solution.

Robust Topology Optimization of Electric Machines using Topological Derivatives

Jason Seeger

TU Darmstadt
Department of Mathematics

We consider PDE-constrained topology optimization problems under parameter uncertainty and present a novel framework using a robust topological derivative. To this end, the robust optimization problem is formulated as a min-max problem $\min_{\Omega\in\mathcal{E}} \max_{p\in\mathcal{U}} \mathfrak{J}(\Omega; p)$. Here, the inner maximization yields the worst-case of our objective function on an uncertainty set. Consequently, the outer minimization aims to find an optimal topology that remains robust under these uncertainties. We show that the worst-case objective functional admits a topological derivative which can be computed efficiently by using the classical topological derivative. The resulting robust topological derivative is then used in a level-set algorithm to determine an optimal robust topology design. Finally, numerical results for a two-material permanent magnet synchronous machine demonstrate both the effectiveness of the method and the improved performance of robust designs under uncertain conditions. This is joint work with Theodor Komann and Stefan Ulbrich from TU Darmstadt, as well as Nepomuk Krenn and Peter Gangl from the Radon Institute for Computational and Applied Mathematics of the Austrian Academy of Sciences.

A Sensitivity and Adjoint Calculus for Optimal Control of Discontinuous Solutions of Hyperbolic Systems of Balance Laws

Stefan Ulbrich

TU Darmstadt
Department of Mathematics

In this talk, we analyze optimal control problems for strictly hyperbolic systems of balance laws where the control is the initial state of the system. The problem is interesting, for example, in the context of fluid mechanics or traffic flow modeling. We consider the Generalized Riemann Problem which has a piecewise C^1 initial state with one discontinuity. We obtain the existence, uniqueness, and stability of a piecewise C^1 entropy solution. Its smooth parts are separated by shock curves. We prove that the shock curves depend differentiably on the initial state. Moreover, we prove that in regions between the shock curves, the entropy solution depends differentiably on the initial state in the topology of C^0. As an immediate consequence, the differentiability of tracking type objective functionals follows. In the second part of this talk, we discuss the adjoint problem as an efficient way to compute the gradient of the objective functional. The adjoint problem is a linear system of transport equations with a discontinuous coefficient and discontinuous terminal data. We derive interior boundary conditions along the shock curves to characterize the correct reversible solution and show that the reversible solution yields the correct adjoint gradient representation.

How to find the correct function space for second-order optimality conditions?

Gerd Wachsmuth

BTU Cottbus-Senftenberg
Mathematik

We consider optimization problems which can be modelled as

$$\min_{x \in X} f(x) + g(x),$$

where X is a dual space, $f\colon X \to \mathbb{R}$ is assumed to be smooth, and $g\colon X \to \mathbb{R} \cup \{\infty\}$. Second-order optimality conditions can be derived using the so-called weak-$\star$ second subderivative under a so-called non-degeneracy condition (NDC). For this, the choice of the "correct" space X is crucial. We illustrate this with two concrete examples in which some progress has been made recently. However, a final answer to the question in the title seems to be elusive. The talk is partially based on joint work with Nicolas Borchard, Constantin Christof, Christian Meyer, Daniel Wachsmuth and Daniel Walter.

Nonconvex regularization in sparse minimization problems

Daniel Walter

Johannes Kepler Universität
Mathematik

Efficiently Solving Nonlinear Time-Dependent Problems from the Geosciences

Gabriel Wittum

TechSim

We present an investigation on the efficient numerical solution of nonlinear time-dependent problems like density driven and multiphase flow and transport problems in porous media. To that end, we investigate the coupling between nonlinear solver and time stepping. In particular, we compare a fixed step time-stepping and inner Newton-like method with an adaptive time-stepping method and simplified non-linear solver of extrapolation type (LIMEX). Numerical experiments include various density-driven flow and carbon-dioxide sequestration problems including parallel scaling studies. The models are implemented in the software package UG4 and the arising linear equations solved by a fully coupled multi-grid solver. Based on these components, this work derives guidelines for the design of an efficient solver.