Abstract. The workshop focussed on various aspects of optimal control problems for systems of nonlinear partial differential equations. In particular, discussions around keynote presentations in the areas of optimal control of nonlinear/non-smooth systems, optimal control of systems involving nonlocal operators, shape and topology optimization, feedback control and stabilization, sparse control, and associated numerical analysis as well as design and analysis of solution algorithms were promoted. Moreover, also aspects of control of fluid structure interaction problems as well as problems arising in the optimal control of quantum systems were considered.

Introduction by the Organisers

Optimal control problems for partial differential equations or variational inequalities nowadays increasingly penetrate the applied sciences and by doing so they are confronted with major new challenges. As a result, besides new mathematical models, novel analytical as well as numerical tools need to be developed. Correspondingly, motivated by optimal control problems for nonlinear partial differential equation (PDE) systems which are related to practical applications, the aims of the workshop were to bring together a group of international experts working at the forefront of research in the field, to foster in-depth-discussions crystallizing around a number of keynote presentations as well as discussion groups on
focal topics emerging during the workshop, and to establish an (international) ex-
change forum for problems, techniques and solutions, both analytically as well as
numerically. In particular, the organizers also strived for diversity in the group of
invited scientists in order to enable transfer of information from senior to young
researchers, and vice versa.

The scientific activity of the workshop developed around several keynote top-
ics with associated keynote presentations, ad hoc presentations, e.g., in the late
afternoon or evening, and the organization of discussion groups on emerging focal
points. Among the focus topics, the following ones were of particular interest:

- **Control of nonlinear or non-smooth state systems.** Starting points
  for the discussion were, e.g., state systems of (quasi) variational inequality
  ((Q)VI) type with applications in thermodynamics or chemotaxis. Specif-
  ically, advanced analysis of the control-to-state map and the derivation of
  proper (sharp) stationarity conditions were focus points. Moreover, local
  stability analysis (in the spirit of second-order conditions) was considered.

- **Control of state systems with nonlocal operators.** Specific exam-
  ples which were highlighted are nonlocal convective Cahn-Hilliard sys-
  tems, systems for describing non-isothermal phase transitions, and non-
  local Cahn-Hilliard-Navier-Stokes systems. Additional complexities came
  from degenerate mobilities or singular potentials, and connections to non-
  smooth systems arise whenever non-smooth potentials, such as the double
  obstacle potential, were considered.

- **Shape and topology optimization.** This is an important branch of
  optimal design subject to partial differential equations with many appli-
  cations in engineering and recently also biomedical sciences. Specific topics
  of interest discussed at the meeting were the establishment of analytical
  tools for enabling a joint shape and topological derivative (currently, and
  apart from a very small number of attempts, these two concepts are still
  considered in separate), second-order analysis, and problems with non-
  smooth components, either in the data or through considering VI state
  systems.

- **Feedback control or stabilization.** Feedback stabilization or control
  are important topics not only in aero-dynamics, but also in other problems
  involving fluid flow such as stabilization of unsteady flow, flow over sur-
  faces, injection of polymer solutions, mass transport through porous walls,
  etc. Some of the major research questions discussed during the meeting
  involved the type of feedback law (linear vs. nonlinear), the proper choice
  of Lyapunov functionals, and the treatment of Riccati equations. The
  latter also play a role for instance in applications of robust optimal place-
  ment of sensor networks. This problem class was also considered in this
  workshop, and it was highlighted that it typically requires to develop suit-
  able solution techniques for ultra-high dimensional Riccati equations upon
  discretization.
• **Sparse control.** Very recently non-smooth control problems with the aim of computing optimal controls with sparse support set have come into focus. Particular applications are related to the optimal placement of actuators. But there is also a connection to inverse problems with sparsity-promoting priors. The workshop focused on modeling, analysis and numerics for such problems. In particular, as the associated optimal controls are typically measures only, dualization frameworks (including the sound understanding of dense embeddings of classes of convex sets in Sobolev spaces) were studied, proper stationarity and stability concepts were derived and optimal discretization schemes were addressed.

• **Numerical analysis and algorithm design / analysis.** As many of the aforementioned problem classes are either entirely new or have been studied from an analytical point of view only, the workshop also strived for advancing the development of proper discretization and numerical solution schemes. Exemplarily we mention that optimal control problems for VIs cannot be solved by techniques known for the iterative solution of optimal control problems for PDE-systems. This is related to the non-smooth character of the VI problem and the constraint degeneracy which prevents existence of Karush-Kuhn-Tucker-type multipliers. Another example is related to sparse controls which gives rise to questions concerning the discretization of measures and their efficient numerical treatment.

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Workshop: Challenges in Optimal Control of Nonlinear PDE-Systems

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