KoMSO Challenge Workshop

"Reduced-Order Modeling for Simulation and Optimization: Powerful Algorithms as Key Enablers for Scientific Computing"

November 17-18, 2016
Robert Bosch GmbH / Corporate Research
Bosch Research Campus, Renningen, Germany

1 Jumping-off Point

Growing demand for numerical solutions in scientific computing – modeling, simulation, data analysis, and optimization problems in many application fields – requires ever-higher algorithmic and computational performance.

It has been shown in many cases that the advancement of mathematical algorithms has increased the arithmetic performance clearly more than the improvements of computer hardware. For that reason Dr. Winfried Keiper (Robert Bosch GmbH / Corporate Research) contacted the Forschungsverbund Wissenschaftliches Rechnen Baden-Württemberg (WiR-BaWü) in autumn 2015 to initiate a stronger impact of advanced mathematical algorithms in industrial applications. As a first step a Challenge Workshop was organized by the Committee for Mathematical Modeling, Simulation and Optimization (KoMSO), by Dr. W. Keiper and Prof. Dr. Stefan Kurz (Robert Bosch GmbH) as well as by Prof. Dr. Stefan Volkwein (University of Konstanz) at the Bosch Research Campus in Renningen.

This KoMSO Challenge Workshop put particular emphasis on the advancement of efficient numerical procedures in the area of model order reduction (MOR) for simulation, optimization and control. Presentations included the introduction of new out-of-the-box algorithmic solutions for scientific computing, e.g. reduced basis methods for industrial problems and MOR approaches for electrochemical processes. The workshop served as platform to bring together the creators and developers of new, optimal fast mathematical algorithms and the industrial users of these tools. Requirements, application fields, needs, and benefits of effort-saving fast algorithms were presented and discussed.

2 Challenge Workshop

The challenge workshop "Reduced-Order Modeling for Simulation and Optimization" was organized by KoMSO with financial support from the Federal Ministry of Education and Research (BMBF) via the "Accompanying Networks" project (IMNET) as well as the working group Numerical Optimization at the University of Konstanz. Local organization was provided by the Robert Bosch GmbH / Corporate Research.

The speakers and participants included industry representatives from BASF SE, Robert Bosch GmbH, SEW Eurodrive, SICOS BW GmbH, and Siemens AG. In addition, representatives from the following institutions participated and/or presented in the workshop: Fraunhofer ITWM Kaiserslautern, Heidelberg University, MPI Magdeburg, Paderborn University, Russian Academy of Sciences, TU Berlin, TU

Darmstadt, TU Munich, Ulm University, University of Hamburg, University of Konstanz, and University of Stuttgart.

3 Major Topics

The discussion concentrated on the question of how numerical solutions in scientific computing can support reduced-order modeling for simulation and optimization in order to

- solve numerically complex, parameter-dependent dynamical problems for multiple parameter choices;
- enable multi-objective optimization with a huge number of design variables and objectives (arising in PDE-constrained optimization);
- deal with PDE-constrained optimal control problems;
- simulate large-scale energy networks (in particular, gas pipeline networks);
- solve PDE-constrained optimization problems under uncertainty in a robust way;
- combine adaptive finite element methods with reduced-order modeling;
- get reliable numerical models for highly dynamic car crash simulations.

It became apparent during the workshop that implementing physical properties of the systems to be modeled offers a huge potential for MOR by algorithms, with massive reduction of computation time. These topics were intensively discussed. Moreover, different MOR techniques were addressed, such as reduced basis methods, proper orthogonal decomposition, tensor decomposition methods and Krylov-based methods.

4 Challenges

Numerous topics for research projects have been identified during presentations and discussions. The participants of the workshop clearly stated that there is a need to investigate in reduced-order modeling. To be more precise, there are many needs for error control in nonlinear MOR, for the development of structure-preserving MOR, or for a numerically efficient combination of MOR and (multi-objective) optimization, optimal control, and design. Moreover, it is necessary to improve advanced numerical algorithms in such a way that they are applicable in industrial use cases.

Reduced-order modeling for simulation and optimization requires the development of novel methods that

- exploit the fact that Moore's law does not further drive CPU speed but rather parallelization;
- can deal with non-robust model evaluations (e.g. solver crash after re-meshing);
- can bound the error due to MOR;
- can deal efficiently with uncertainty;
- take into account physical properties and correlations in an interdisciplinary manner;
- allows for the computation of feedback controls in nonlinear problems.

A big challenge is “closing the gap” between the creative ideas and their formal mathematical formulations on the side of the mathematicians, and concrete industrial applications and needs, with often vaguely formulated conditions and requirements. The activities of WiR-BaWü and KoMSO, and this workshop in particular, are trying to bridge this gap.
In addition, software developers need to be involved more strongly, which is essential for putting new MOR algorithms on the road.

5 Outlook

All participants agreed that the workshop offered a much-needed platform to raise awareness of benefits that are possible by making advanced numerical methods in MOR applicable for real world problems. In collaboration with Springer Verlag it is planned to publish a special volume (expected publication in 2017). The participants realized that the two-day workshop was too short to discuss all relevant topics in sufficient detail. It has been suggested to organize a follow-up conference and to investigate possibilities for setting up specific joint research projects.