Young Researchers Meeting and

Workshop on Modeling, Simulation & Optimization of Fluid Dynamic Applications

(MSO Groß Schwansee 2022)

Book of abstracts

GRK 2583

21. - 24.03.2022

Contents

Young Researchers Meeting (YRM) - Mon, 21.03.2022

Programm

Session I: 13:00 - 14:30

13:00 - 13:30: Judith Angel (TUHH)

Bathymetry Reconstruction for the Shallow Water Equations

For the numerical simulation of tsunamis, a model of the bathymetry, the topography of the ocean bottom, is indispensable as it greatly impacts the behavior of the wave. It is possible to approximately reconstruct the bathymetry from measurements of the water height by solving an optimisation problem with the shallow water equations as constraints. Following the derivation of the required adjoint equation we will present suitable numerical methods and show computational results.

13:00 - 13:30: Hamzah Bakthi (UHH)

Modeling and simulation of parabolic trough power plant using various heat transfer fluids and nanofluids: Application to NOOR I plant in Ouarzazate, Morocco

A mathematical model is built to describe the fluid dynamics for different heat transfer fluids in a parabolic trough power plant. Generally, the power plant consists of a network of tubes for the flow of a heat transport fluid. This paper focuses on the analysis of using nanofluids in such power plants, where a numerical approach is presented for single tube model and also for realistic network settings. In addition, the performance of the power plant is studied via analyzing the obtained power output and the energy efficiency of the different systems. The proposed mathematical model takes into account the real system parameter and external conditions from NOOR I power plant in Ouarzazate, Morocco. Effects of different system parameters on the output energy are conducted in order to obtain the best conditions of utilization in parabolic trough power plant.

14:00 - 14:30: Stephanie Blanke (UHH)

Motion Compensation for Magnetic Particle Imaging using an FFL-Scanner

A mathematical model is built to describe the fluid dynamics for different heat transfer fluids in a parabolic trough power plant. Generally, the power plant consists of a network of tubes for the flow of a heat transport fluid. This paper focuses on the analysis of using nanofluids in such power plants, where a numerical approach is presented for single tube model and also for realistic network settings. In addition, the performance of the power plant is studied via analyzing the obtained power output and the energy efficiency of the different systems. The proposed mathematical model takes into account the real system parameter and external conditions from NOOR I power plant in Ouarzazate, Morocco. Effects of different system parameters on the output energy are conducted in order to obtain the best conditions of utilization in parabolic trough power plant.

Session II: 15:00 - 16:00

15:00 - 15:30: Rebekka Beddig (TUHH)

An error-based low-rank correction for
pressure Schur complement preconditioners

We describe a multiplicative low-rank correction scheme for pressure Schur complement preconditioners to accelerate the iterative solution of the linearized Navier-Stokes equations. The application of interest is a model for buoyancy-driven fluid flows described by the Boussinesq approximation which combines the Navier-Stokes equations enhanced with a Coriolis term and a temperature advection-diffusion equation. The update method is based on a (best) low-rank approximation to the error between the identity and the preconditioned Schur complement. Numerical results on a cube and a shell geometry illustrate the action of the low-rank correction on spectra of preconditioned Schur complements using known preconditioning techniques, the BFBt method and the SIMPLE method. Computational costs of the update method are also investigated. The goal is to identify settings in which such update methods can lead to accelerated solvers.

15:30 - 16:00: Niko Schmidt (CAU Kiel)

Iterative solver for ice models

The momentum equation for ice models are nonlinear partial differential equations, called p-Stokes equations (or in application Full Stokes equations). Classically the Picard iteration is used, which is regarding to use in practice globally convergent, but slow. We consider damped Newton methods to get faster convergence and to prove local convergence for a slightly different equation. (We add $\mu_0(\nabla v, \nabla \phi)$ to be able to calculate the next iteration.)

In a second step we show global convergence with a Trust-Region method. At the end we compare a Picard iteration and a Newton iteration with Armijo step-size rule with respect to number of iterations and effort for a mathematical test problem.

Modeling, Simulation & Optimization of Fluid Dynamic Applications (MSO) - Tue, 22.03.2022

Programm

Invited Lecture

13:00 - 14:00: Michael Hinze (Universität Koblenz-Landau)

Adaptive construction concepts for the prediction horizon in MPC of PDE systems

The core of the Model Predictive Control (MPC) method in every step of the algorithm consists in solving a time-dependent optimization problem on the prediction horizon of the MPC algorithm, and then to apply a portion of the optimal control over the application horizon to obtain the new state. To solve this problem efficiently, we propose a time- adaptive residual a-posteriori error control concept based on the optimality system of this optimal control problem. This approach not only delivers a tailored time discretization of the the prediction horizon, but also suggests a tailored length of the application horizon for the current MPC step. We apply this concept for systems governed by linear parabolic PDEs and present several numerical examples which demonstrate the performance and the robustness of our adaptive MPC control concept.

Joint work with Carmen Gräßle (TU Braunschweig) and Allessandro Alla (Venedig).

Session I: 14:00 - 15:00

14:30 - 15:00: Christian Kahle (Uni Koblenz-Landau)

Optimal control of sliding droplets using the contact angle

We present results on optimal control of sliding droplets. Here the contact angle between droplet and solid serves as a control variable. The fluid is modelled by a thermodynamically consistent diffuse interface model with a suitable contact line model. In earlier work [H. Bonart, C. Kahle, J.-U. Repke, JCP 399 (2019)] we compared different time discretization schemes for this model that mimics the energy behaviour of the continuous model. We now employ a particular scheme to derive existence of optimal controls for a time discrete optimal control problem and also first order necessary conditions. As controls we consider finite dimensional controls for the contact angle distribution. We test our approach by driving a droplet up an inclined plate.

14:30 - 15:00: Hendrik Ranocha (UHH)

Analysis Meets Data: Efficient Implementation and Optimized Time Integration Methods with Automatic Step Size Control for Compressible Computational Fluid Dynamics

Modern entropy-dissipative numerical methods for computational fluid dynamics (CFD) increase the robustness compared to standard schemes significantly. At the same time, their implementation becomes more involved and it is more difficult to achieve good performance. We briefly mention techniques for the efficient implementation of these methods and focus on the analysis and development of adaptive time integration methods for high-order entropy-stable spatial discretizations. We develop error-control based time integration algorithms and show that they are efficient and robust in both the accuracy-limited and stability-limited regime for CFD applications using discontinuous spectral element discretizations. We demonstrate the importance of choosing adequate controller parameters and provide a means to obtain these in practice by combining analysis with a data-driven approach, which we apply to design new controllers for existing methods and for some new embedded Runge-Kutta pairs. We compare a wide range of error-control-based methods, along with the common approach in which step size control is based on the Courant-Friedrichs-

Lewy (CFL) number. The new optimized methods give improved performance and naturally adopt a step size close to the maximum stable CFL number at loose tolerances, while additionally providing control of the temporal error at tighter tolerances. The numerical examples include challenging industrial CFD applications.

Session II: 15:30 - 17:00

15:30 - 16:00: Benedict Philippi (CAU Kiel)

Applying Parareal to Fluid Problems

The usecase of parallelization in time begins when runtime reductions by spatial parallelization techniques are coming to an end. This talk addresses the Parareal algorithm, which splits the temporal domain into multiple parts and solves a given problem on each part iteratively and in parallel. It is well-known to be efficient for a restricted set of problems only, e.g. the Heat equation. When it comes to wave equations or applications in fluid mechanics the algorithm's convergence rate deteriorates or even stalls. The additional (massive) computational effort following Parallel-In-Time algorithms then ceases to justify its cost. To overcome some of these deficiencies either very problem-specific coarse solvers are needed to be developed or the iteration scheme of Parareal is sought to be modified. The latter option proved itself as very efficient for linear PDEs. Decomposition of the linear system matrix allows for a component-wise update scheme that converges in very few iterations, even for oscillatory problems. This talk dives into the modification to Parareal and its application to a range of PDEs, from linear to selected inhomogeneous and non-linear models.

16:30 - 17:00: Thomas Slawig (CAU Kiel)

Micro-macro parallel-in-time computations for turbulent flow with OpenFOAM

We realized the micro-macro parareal algorithm for turbulent channel flow around a circular cylindrical body. The parareal algorithm, introduced by Lions Madam Turinici, is the most popular algorithm to realize a parallelization in time for initial-boundary value problems of PDEs. In the micro- macro version, a coarse propagator on a coarser spatial grid is used as predictor, whereas a fine propagator on the finer target grid is applied in parallel on different time slices. In every iteration, a coarse solver is applied as corrector or update. Using two different grids requires a mapping procedure. In theory, this procedure is straight-forward. However, in practical implementations (as for example OpenFOAM), one has to struggle with several technical difficulties. We show how these difficulties can be addressed and what results we obtained.

17:00 - 17:30: Kristof Albrecht (UHH)

Greedy methods for kernel-based generalized interpolation and their application to computerized tomography

Positive definite kernel functions are powerful tools for numerous mathematical problems. While most kernel-based methods use kernel functions in the context of standard Lagrangian interpolation, kernel functions are also well-suited for generalized interpolation problems due to the structure of their native space. Similar to the standard case, the generalized interpolation problem is often ill-conditioned, e.g. for large data sets. Therefore, we will discuss generalizations of well- known greedy data selection algorithms from standard Lagrangian interpolation.

Moreover, we will discuss the application of kernel-based generalized interpolation to computerized tomography, as it was proposed by S. De Marchi, A. Iske and G. Santin in 2018. The proposed reconstruction method and the effects of the different greedy algorithms will be illustrated by numerical examples.

Modeling, Simulation & Optimization of Fluid Dynamic Applications (MSO) - Wed, 23.03.2022

Programm

Invited Lecture

09:00 - 10:00: Alfio Borzi (JMU Würzburg)

Investigation of optimal control problems governed by kinetic models

Since the pioneering work of Ludwig E. Boltzmann, the configuration of multi-particle systems is conveniently represented by a material (alternatively, probabilistic) density and the evolution of this density is modelled by kinetic equations.

These models are widely applied in diverse problems ranging from pedestrian motion to rarefied gases, and most applications require the design of control mechanisms to steer the systems in order to perform given tasks.

In this talk, theoretical and numerical results are presented concerning optimal control problems with kinetic models having different structures, including space-inhomogeneous models with collision terms and different control mechanisms.

Session III: 10:00 - 10:30

10:00 - 10:30: Fabian Bleitner (UHH)

Lower Bounds for the Advection-Hyperdiffusion equation

Inspired by the work of Nobili and Pottel [1] on mixing estimates for the Advection-Diffusion equation we study the Advection-Hyperdiffusion equation on the whole space in two and three dimensions with the goal of understanding the decay of the H1- and L2-norm in time. We view the advection as a perturbation of the hyperdiffusion equation and employ the Fourier Splitting method first introduced by Schonbek in [2] for scalar parabolic equations and later generalized to a broad class of equations including Navier Stokes equations and Magneto Hydrodynamic systems. This approach consists of decomposing the Fourier space along a sphere with radius decreasing in time. Combining the Fourier splitting method with classical PDE techniques applied to the hyperdiffusion equation we find a lower bound for the H1-norm by interpolation.

[1] C. Nobili and S. Pottel. Lower bounds on mixing norms for the advection diffusion equation in Rd. In: Preprint at arXiv:2006.04614 (2020).
[2] Maria Elena Schonbek. Decay of solution to parabolic conservation laws. In: Communications in Partial Differential Equations 5.4 (1980), pp. 449–473. eprint: https://doi.org/10.1080/03605308008821145.

Session IV: 11:00 - 12:00

11:00 - 11:30 Malte Braack (CAU Kiel)

Outflow conditions for incompressible and Boussinesq flow

We propose boundary conditions for incompressible flows to model free outflow. In comparison with the standard do-nothing condition, we add certain nonlinear terms to the boundary conditions. We present the method for the Navier-Stokes and the Boussinesq system. In the latter case of non-constant temperature, the boundary condition for the temperature should be modified as well. For stability reasons, we consider weak implementations of all Dirichlet boundary conditions. The resulting system is stable and allows for proving existence of weak solutions in 2D and 3D. In order to obtain a stable discrete system we use equal-order finite elements with local projection stabilization. We give an error estimate for the discrete solution. By numerical simulations of the proposed system and comparisons with standard outflow conditions we show that the new system is more robust.

11:30 - 12:00 Jörn Behrens (UHH)

Reflections about uncertainty

Over the last years and in the frame of the Excellence Cluster CLICCS, I have conducted an interdisciplinary course series on uncertainty. This brought up a number of interesting aspects on uncertainty, which may be particularly interesting to mathematicians, engineers and natural scientists, who are involved in modeling and simulation. I would like to review a few terms related to uncertainty.

While uncertainty quantification is a well established field in mathematical and computational sciences, this talk will deviate from this strictly defined field and will take a more fundamental view on uncertainty. This touches our role and approaches as scientists. I thought, this would be of interest in particular to early career scientists. substantiated.

Session V: 13:00 - 14:30

13:00 - 13:30 Henrik Wyscha (UHH)

Towards computing high-order p-harmonic descent directions and their limits in shape optimization

Shape optimization constrained to partial differential equations is a vivid field of research with high relevance for industrial grade applications. Recent development suggests that using a p-harmonic approach to determine descent directions is superior to classical Hilbert space methods [2]. A shape is described by a part of the boundary of the computational domain which is free for deformation. For optimization algorithms the sensitivity of the cost function with respect to variations of the shape has to be represented in an appropriate space of deformations. In the p-harmonic approach, the descending deformations are obtained by the solution of a p-Laplace problem with a Neumann condition on the free boundary and homogeneous Dirichlet conditions on the remaining boundary of the computational domain.

State-of-the-art numerical algorithms for this type of problem require an iteration over the order p and break down from numerical problems when trying to archive higher orders $p > 5$. We adapt the idea of solving scalar Dirichlet problems for the p-Laplacian using interior-point methods [1] to provide an efficient algorithm for the variational problem associated to the descent directions. This enables us to perform computations without iterating the order, providing high-order solutions verified by numerical experiments for a fluid dynamic setting in 2 and 3 dimensions. A general requirement on the resulting transformations of the computational domain is to keep it of Lipschitz type. While solutions for finite p yield approximations in $W^{1,p}$, analytically only descent directions in $W^{1,\infty}$ are admissible. This is challenging since the ∞-Laplace equation itself is in general not the limit of the corresponding p-Laplace equations. Further, the solutions may be non-unique due to the change of signs in the source term necessary for shape optimization. We make progress towards a novel algorithm for ∞-Laplace problems providing admissible descent directions that are the limit of the p-harmonic deformations.

References

[1] Sébastien Loisel. Efficient algorithms for solving the p-Laplacian in polynomial time. Numerische Mathematik, 146(2):369–400, 2020.

[2] Peter Marvin Müller, Niklas Kühl, Martin Siebenborn, Klaus Deckelnick, Michael Hinze, and Thomas Rung. A Novel p-Harmonic Descent Approach Applied to Fluid Dynamic Shape Optimization. Structural and Mulitdisciplinary Optimization, 2021.

13:30 - 14:00 Lukas Schlegel (Uni Trier)

Shape Optimization for the Mitigation of Coastal Erosion via Smoothed Particle Hydrodynamics

Adjoint-based shape optimization most often relies on Eulerian flow field formulations. However, since Lagrangian particle methods are the natural choice for solving sedimentation problems in oceanography, extensions to the Lagrangian framework are desirable. For the mitigation of coastal erosion, we perform shape optimization for fluid flows, that are described by incompressible Navier-Stokes equations and discretized via Smoothed Particle Hydrodynamics. The obstacle's shape is hereby optimized over an appropriate cost function to minimize the height of water waves along the shoreline based on shape calculus. Theoretical results will be numerically verified exploring different scenarios.

14:00 - 14:30: Kamal Sharma (UHH)

Numerical simulation of an idealized coupled ocean-atmosphere model

We present numerical simulation of an idealized climate model. Our climate model belongs to the class of intermediate coupled models which are much simpler than the coupled general circulation models of the ocean-atmosphere system but still allow to study the fundamental aspects of ocean-atmosphere interactions. Our model couples an atmospheric system, described by the compressible two-dimensional (2D) Navier-Stokes equations and an advection-diffusion equation for temperature, to an ocean system, given by 2D incompressible Navier-Stokes equations and an advection-diffusion equation for temperature. Finite element method is used to discretize the system of PDEs representing the climate model on a 2D unit-square periodic domain and the implementation is done using

Firedrake*, which is an efficient automated finite element method library. To ensure the accuracy of simulation results of the coupled model, we have carried out detailed numerical investigation of its atmospheric and ocean components separately (without coupling) and tested our codes against different benchmark problems available in the literature. Our final aim is to incorporate stochasticity into the coupled ocean-atmosphere model following the Hasselmann's paradigm [1] and use the model to study important climate phenomena like El-Nino Southern Oscillation (ENSO) [2] which occur in the tropical eastern Pacific Ocean as a result of strong ocean-atmosphere interactions. This will be the subject of our future work.

References:

[1] Klaus Hasselmann. "Stochastic climate models part I. Theory". In: tellus 28.6 (1976), pp. 473–485.

[2] Henk A Dijkstra. Nonlinear physical oceanography: a dynamical systems approach to the large scale ocean circulation and El Nino. Vol. 28. Springer Science & Business Media, 2005.

Session VI: 15:00 - 16:00

14:00 - 14:30 Tim Suchan (HSU)

Optimization of multiple shapes for a fluid-mechanical problem

Shape optimization has been an active field of research for the past decades and is used for example in engineering. Many relevant problems in the area of shape optimization involve a constraint in the form of a partial differential equation. In this talk, we concentrate on the Stokes equation and consider an objective function depending on multiple shapes. To handle problems where an objective function depends on multiple shapes, we need a theoretical framework, whereby the optimization variable can be represented as a vector of shapes belonging to a product shape space. Using an approach based on the Steklov-Poincaré metric and the so-called multi-shape derivative we present a gradient descent algorithm using Armijo backtracking stepsize control to solve multi-shape optimization problems. We apply our method to the minimization of viscous energy dissipation subject to the Stokes equations. Additional care is needed when the constraints contain inputs or material properties subject to uncertainty. Thus, we take a short glance at the minimization of viscous energy dissipation subject to the Stokes equations under uncertainty.

Acknowledgments:

This work has been partly supported by the state of Hamburg (Germany) within the Landesforschungsförderung within the project "Simulation-Based Design Optimization of Dynamic Systems Under Uncertainties" (SENSUS).

14:00 - 14:30 Marvin Müller (TUHH)

Application of p-Laplacian relaxed steepest descent to technical free surface flows

The contribution aims to scrutinize the p-Laplacian relaxed steepest descent approach to turbulent free surface flows. To this end, the approach introduced in [1, 2] is applied to the minimization of fluid dynamic drag in 3D high Reynolds-number test cases. Comparisons involve state-of-the-art approaches [3, 4], the Hilbertspace baseline method ($p = 2$) as well as larger values of p to outline the advantages. It is demonstrated that the p-Laplacian approach reduces the number of shapes visited during the optimization process and preserves quality of the computational mesh - even for optima that feature edges or corners, cf. Fig. 1 (top). Applications included refer to generic shapes and merchant marine vessel hulls exposed to two-phase flows as depicted by Fig. 1.

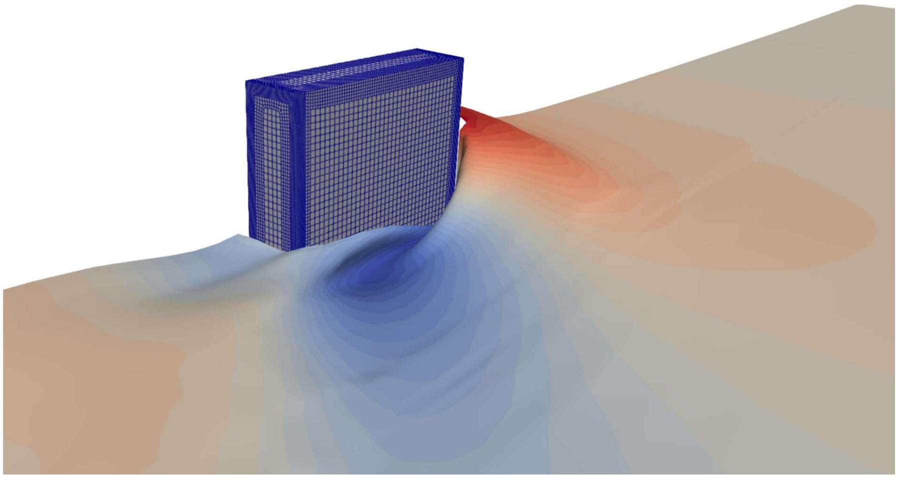

Fig. 1: Free-surface elevation for a partially submerged box at Reynolds and Froude numbers of $Re = 1.7 \cdot 10^5,\ Fn = 0.71$ (top) and a MOERI container ship (http://www.simman2008.dk/KCS/kcs_geometry.htm) at $Re = 1.43 \cdot 10^7,\ Fn = 0.26$ (bottom).

References:

[1] K. Deckelnick, P. J. Herbert, and M. Hinze. "A Novel $W^{1,\infty}$ Approach to Shape Optimization with Lipschitz Domains". In: ESAIM: COCV 28 (2022). doi: 10.1051/cocv/2021108.

[2] P. M. Müller et al. "A novel p-harmonic descent approach applied to fluid dynamic shape optimization". In: Struct Multidic Optim 64 (2021). doi: 10.1051/cocv/2021108.

[3] S. Onyshkevych and M. Siebenborn. "Mesh Quality Preserving Shape Optimization Using Nonlinear Extension Operators". In: Journal of Optimization Theory and Applications 189 (2020), pp. 291–316. doi: 10.1007/s10957-021-01837-8.

[4] V. Schulz and Siebenborn M. "Computational Comparison of Surface Metrics for PDE Constrained Shape Optimization". In: Computational Methods in Applied Mathematics 16.3 (2016), pp. 485–496. doi: 10.1515/cmam-2016-0009.

Invited Lecture

16:00 - 17:00 Kathrin Padberg-Gehle (Leuphana Uni Lüneburg)

Identification and characterization of coherent behavior in flows

The motion of tracers in fluids flows is crucially influenced by coherent structures. Due to their strong impact on global transport and mixing processes the characterization of these Lagrangian objects is a topic of intense current research. From a probabilistic point of view, coherent sets are regular regions in the physical domain of the flow that move about with minimal dispersion.

Coherent sets can be efficiently identified via Perron-Frobenius operators (transfer operators). These linear Markov operators can be approximated within a set-oriented numerical framework based on Ulam's method. Subdominant singular values/vectors of the resulting stochastic matrices are then used to determine and characterize the structures of interest. While mathematically sound, transfer operator constructions have some computational disadvantages when studying nonautonomous systems. This has led to the recent development of data-based approaches. In this context, spatio-temporal clustering algorithms have been proven to be very effective for the extraction of coherent sets directly from given trajectories. In particular, a discrete representation of the dynamics in terms of a trajectory network forms the basis of a computationally very attractive and flexible framework, which is also applicable when the underlying data is sparse and incomplete.

In this contribution, we will review these computational approaches and apply them to a number of example systems, including turbulent Rayleigh-Bénard convection flows.

Modeling, Simulation & Optimization of Fluid Dynamic Applications - Thu, 24.03.2022

Programm

Invited Lecture

09:00 - 10:00 Katrin Welker (HSU)

Constrained shape optimization in shape spaces: Models raising from PDE to VI constraints and from deterministic to stochastic settings

A challenge in shape optimization is in the modeling of shapes, which do not inherently have a vector space structure. If one cannot work in vector spaces, one possible approach is to cast the sets of shapes in a Riemannian viewpoint, where each shape is a point on an abstract space like a manifold - or, more generally, a diffeological space—equipped with a notion of distances between shapes. In this talk, we first apply the differential-geometric structure of Riemannian shape spaces to the theory of deterministic shape optimization problems. Since many relevant problems in the area of shape optimization involve a constraint in the form of a partial differential equation, which contains inputs or material properties that may be unknown or subject to uncertainty, we consider also stochastic shape optimization problems. We present a novel method, which is the extension of the classical stochastic gradient method to infinite- dimensional shape manifolds. The method is demonstrated on a shape optimization problem. A motivation for our model is in electrical impedance tomography, where the material distribution of electrical properties such as electric conductivity and permittivity inside the body is to be determined. Additionally, we consider shape optimization problems constrained by variational inequalities (VI).

These problems are highly challenging in contrast to classical VIs, where no explicit dependence on the domain is given. Firstly, one needs to operate in inherently non-linear, non-convex and infinite-dimensional shape spaces. Secondly, one cannot expect the existence of the adjoint state and one cannot expect for an arbitrary shape functional depending on solutions to VIs the existence of the shape derivative or to obtain the shape derivative as a linear mapping. Thus, the problem cannot be solved directly without any regularization techniques.

Acknowledgments: This work has been partly supported by the German

Research Foundation (DFG) within the priority program SPP 1962 under contract number WE 6629/1-1 and by the state of Hamburg (Germany) within the Landesforschungsförderung within the project "Simulation-Based Design Optimization of Dynamic Systems Under Uncertainties."

Session VII: 10:00 - 10:30

11:30 - 12:00 Lars Radtke (TUHH)

Parameter-free shape optimization: Glimpses on sensitivities, gradients and metrics for engineers

In the last decade, parameter-free approaches to shape optimization problems have matured to a state where they provide a versatile tool for complex engineering applications. Instead of parameter-based approaches, they provide the mathematical basis for discretization-independent solutions and a rigorous definition of the space of admissible shapes. Furthermore, the analytical effort in deriving shape derivatives is frequently reduced and itself discretization independent, i.e., it can be combined with different numerical methods in a second step. To this end, the consistency of the shape derivative from parameterized approaches is lost while flexibility is gained.

However, parameter-free or continuous expressions for shape derivatives, cannot be directly used as a descent direction in gradient-based optimization strategies. Instead, a proper descent direction needs to be computed by means of an auxiliary problem, which is connected to the choice for an inner product. While several choices for these auxiliary problems were investigated in the mathematical community, the complexity of the concepts behind their derivation has prevented the engineering community from applying them in practice and taking advantage of this development. Instead, standard choices or comparatively simple smoothing approaches are applied without referencing an inner product and thus lacking a clear definition of space of admissible shapes.

This work aims to introduce several more advanced choices for inner products and give an illustrative explanation of their advantages and disadvantages. This makes them available for communities without a profound mathematical background. Further, the work provides some guidance to the state-of-the-art literature for readers interested in this background. Finally, popular choices for the auxiliary problem are compared by applying them in the context of an illustrative test case and a shape optimization problem from fluid dynamics

Session VIII: 11:00 - 11:30

11:00 - 11:30 Philip Herbert (Uni Koblenz-Landau)

A novel $W^{1,\infty}$ approach to shape optimisation with Lipschitz domains

In this talk, we discuss a novel method for shape optimisation. We propose to use the shape derivative to determine deformation fields which represent directions of steepest descent in the topology of $W^{1,\infty}$. We demonstrate our approach by restricting to star-shaped domains which we represent as functions definted on the unit $(n-1)$-sphere. In this setting we provide the specific form of the shape derivative and show that directions of steepest descent exist. We present several numerical experiments in two dimensions which illustrate our approach. This is based on joint work with Klaus Deckelnick and Michael Hinze.

Invited Lecture

11:30 - 12:30 Volker Schulz (Uni Trier)

On Algorithmic Shape Optimization

Shape optimization is quite often considered from the point of view of shape calculus only. This talk builds up on shape and preshape calculus and discusses various algorithmic approaches towards shape optimization ranging form steepest descent to shape-Newton methods. Several problems from applications will be used as motivation. We will see that different shape concepts provide different means for the analysis of shape optimization algorithms. Finally, a novel framework for the convergence analysis is provided, resulting into the definition of yet another variant of shape Hessians. Benefits and challenges of this new framework are discussed.

List of speakers