Josefin Ahlkrona

Finite Element Discretization of the p-Stokes Equations for Glaciological Applications

The p-Stokes equations describes non-Newtonian fluid flow, and are used to model ice sheet and glacier dynamics. Glacial ice is a shear-thinning fluid, meaning that the viscosity increases with decreasing strain-rates, so that singularities occur in the parameters. Modelling ice dynamics is challenging not only because of this non-linear, singular, rheology but because of complications such as a thin, complex domain shape, uncertain data, a free surface and a large range of relevant space and time-scales. An increasing number of ice sheet models use the finite element method, often with equal order linear elements and isotropic Galerkin Least-Squares stabilization. We describe challenges of such discretizations, and discuss the development of an anisotropic local projection stabilization.

Larisa Beilina,

A new global optimization approach for the solution of hyperbolic coefficient inverse problem

In this talk we will briefly present two-stage global optimization approach for the solution of hyperbolic coefficient inverse problem. On the first stage an approximate globally convergent algorithm rigorously guarantee obtaining at least one point in a small neighborhood of the exact solution without any advanced knowledge of that neighborhood. On the second stage an adaptive finite element method refines the solution obtained on the first stage.

We will demonstrate numerical verification of the two-stage procedure on the reconstruction of refractive indices of inclusions placed in the air as well targets buried in a dry sand from backscattered experimental data provided by the Optoelectronics and Optical Communications Center of University of North Carolina at Charlotte, Charlotte, USA.

Marsha Berger

A Cut-Cell Method for High Reynolds Number Flows

Cut-cell methods are popular for inviscid flow simulations since they handle complicated geometry in a robust and automatic way. They are rarely used for high-Reynolds viscous flows, since isotropic or coordinate-aligned refinement is impractical for resolving boundary layers. This talk presents a method using one-dimensional linelets in each cut cell as a substitute for anisotropic body-fitted boundary layer zoning. We solve a two-point boundary value problem on each linelet, which gives solutions that are more accurate than standard wall functions, and are valid farther from the wall. The linelets are coupled to the outer Cartesian grid in a fully conservative way, with two-way interaction between the linelets and the background grid. We show computational results in two dimensions for a variety of benchmark problems. This is joint work with Michael Aftosmis.

Inga Berre

Numerical modeling of geothermal reservoir stimulation

Hydraulic stimulation is a key technology for exploitation of geotermal resources. Reactivation of fractures in igneous and metamorphic rocks can improve the subsurface heat exchanger by enhancing the permeability of critically oriented fractures with orders of magnitude at pressures elevated below the minimum principal stress. The subsurface processes are characterized by complex THMC couplings, representing severe challenges in mathematical and numerical modeling.

A numerical approach for modeling of reactivation and corresponding shear dilation of fractures in a three-dimensional network surrounded by low-permeable matrix is developed, focusing on the fracture deformation and hydro-mechanical coupling. The approach is based on a conceptual discrete fracture-matrix model, where the dominating fractures are modeled explicitly and surrounded by low-permeable matrix, capturing the effect of small-scale fractures on the flow. The rock matrix is assumed to be linearly elastic, while a fracture deformation model handles the frictional shear-slip and dilation of the fractures. Numerically, recently develop finite-volume type discretizations are utilized, where the fracture and

matrix domain are coupled by internal boundary conditions. Results contributing to enhanced understanding of significant physical mechanisms in reactivation of fracture networks are presented.

Yekaterina Epshteyn,

High-Order Accurate Numerical Methods for Elliptic and Parabolic Interface Models

Abstract. Designing numerical methods with high-order accuracy for problems with interfaces (for example, models for polycrystalline materials or composite fluids, etc.), as well as models in irregular domains is crucial to many applications in materials science, biology and physics.

In this talk we will present recently developed efficient numerical schemes based on the idea of the Difference Potentials for elliptic and parabolic composite domain/interface problems. Numerical experiments to illustrate high-order accuracy and the robustness of the developed methods will be given. Current and future research will be discussed as well.

Donna Calhoun

Multi-rate Runge-Kutta-Chebyschev time-stepping for parabolic equations on adaptively refined meshes

Adaptive mesh refinement (AMR) is widely recognized as a way to use computational resources efficiently. Often used to improve the performance of finite volume or finite difference methods on logically Cartesian meshes, an adaptive mesh strategy dynamically allocates mesh resources in regions in the computational domain where the demands for resolution are the highest. When using explicit time stepping schemes on adaptive meshes, it is often advantageous to use local time stepping as well, and allow coarser regions of the domain to take larger time steps than finer regions.

Runge-Kutta-Chebyschev (RKC) methods are a class of stabilized, single step, multi-stage explicit time stepping methods designed to efficiently solve mildly stiff differential equations. RKC schemes are

relatively easy to implement and have low storage requirements, and so are ideal candidates for solving parabolic partial differential equations using a method-of-lines approach. While parabolic equations are most commonly solved using implicit methods, explicit methods are generally easier to implement, especially for non-uniform or adaptive meshes, or for coupled systems of parabolic equations. Furthermore, they are {\em direct} in the sense that the solution at time T can be obtained after a number of steps that is known a priori. Finally, when combining diffusion with other operators (e.g. advection), operator splitting errors can be avoided if methods for both schemes are explicit.

We have developed an algorithm which uses RKC time stepping for adaptive refinement in time and space. The essential component in the algorithm is a mechanism for interleaving the stage progression between levels and interpolating in time between stages when spatial refinement levels are not time synchronized. We have used this algorithm for solving a one-dimensional heat equation on an adaptively refined mesh, and find that, depending on the refinement strategy, time savings using both adaptivity in time and space can be significant, when compared to solving the equivalent problem on a uniformly refined mesh. We also present results using ForestClaw, a two-dimensional block-structured quadtree code for solving two dimensional hyperbolic problems on adaptively refined finite volume meshes. Applications of interest are reaction-diffusion problems, including crystal growth, and biological pattern formation.

Sofia Eriksson

A dual consistent finite difference method

We study the numerical solutions of time-dependent systems of partial differential equations, focusing on the implementation of boundary conditions. The numerical method considered is a finite difference scheme constructed by high order summation by parts operators, combined with a boundary procedure using penalties (SBP-SAT). Recently it was shown that SBP-SAT finite difference methods can yield super-convergent functional output if the boundary conditions are imposed such that the discretization is dual consistent. We generalize these results so that they include a broader range of boundary conditions and penalty parameters. The results

are also generalized to hold for narrow-stencil second derivative operators. The derivations are supported by numerical experiments.

Lisa Fauci

Hydrodynamic synchronization in models of internally-driven cilia

Cilia play an important role in many biological processes, including the transport of mucus in the lungs and the locomotion of micro swimmers. Whether occurring in pairs as on a single algal cell or arrays on epithelial cells, their beat pattern is self-organized. Minimal models of colloidal particles driven by optical traps have been used to shed light on the hydrodynamics of synchronization. Here we extend the minimal model that represents a cilium by a bead to one that represents the cilium as an elastic filament. The beat angle of this filament switches between two 'traps', driving the motion of the power and recovery strokes. The cilia are coupled to a viscous fluid using a centerline distribution of regularized Stokeslets. We also present a more detailed model of a cilium that tracks individual dynein molecular motors that are themselves driven by a geometric switch. The action of these motors is realized as forces between neighboring microtubules that comprise the cilium. While each model of a single cilium captures a realistic beat form, the emergent behavior of pairs of cilia are surprisingly different.

Natasha Flyer

Why go mesh-free? Opportunities and Applications

Most numerical computations in multiple dimensions use either structured meshes (e.g. finite differences and spectral methods) or unstructured ones (e.g. finite elements). Radial Basis Functions (RBFs) and, most recently, RBF-generated finite differences (RBF-FD) offer the opportunity of completely mesh-free calculations with current applications in areas such as geosciences, computational chemistry, electrical engineering/physics, etc. The approach combines a number of strengths, including:

- High orders of accuracy,

- Computational efficiency in terms of wall clock time and memory cost

- Geometric flexibility (irregular domain shapes, local node refinements, solutions over curved surfaces and domains with discontinuous interfaces, etc.),

- Short and simple codes in which algorithmic complexity does not increase with dimension

- Good opportunities for parallelization on high performance computing platforms

RBFs were introduced in the 1970s, first as a tool for interpolating scattered 2-D data. Since then, both our knowledge about RBFs and their range of applications have grown tremendously, with the numerical solution of differential equations now becoming a particularly important one. We will demonstrate why and how RBFs and RBF-FD provide a promising innovative approach to solving PDEs.

Christina Frederick

Multiscale methods for seafloor identification in sonar imagery

Modern day sonar systems are capable of obtaining acoustic measurements from the ocean floor with an unprecedented level of precision, yet only about .05% of the oceans are mapped to a resolution of a couple meters. There is a critical need for the development of efficient methods for remote acoustic classification of the seafloor, especially for time-sensitive tasks such as finding plane wreckage. A main computational obstacle is dealing with the complex scattering effects of structures on the ocean floor. I will discuss a recently developed reduced order modeling strategy that incorporates simulations of Helmholtz equations on a wide range of spatial scales, allowing for detailed recovery of seafloor parameters including the sediment type and microtopography.

Brittany Froese

Meshfree finite difference methods for fully nonlinear elliptic equations

The relatively recent introduction of viscosity solutions and the Barles-Souganidis convergence framework have allowed for considerable progress in the numerical solution of fully nonlinear elliptic equations. Convergent, wide-stencil finite difference methods now exist for a variety of problems. However, these schemes are defined only on uniform Cartesian meshes over a rectangular domain. We describe a framework for constructing convergent meshfree finite difference approximations for a class of nonlinear elliptic operators. These approximations are defined on unstructured point clouds, which allows for computation on non-uniform meshes and complicated geometries. Because the schemes are monotone, they fit within the Barles-Souganidis convergence framework and can serve as a foundation for higher-order filtered methods. We present computational results for several examples including problems posed on random point clouds, computation of convex envelopes, obstacle problems, Monge-Ampere equations, and non-continuous solutions of the prescribed Gaussian curvature equation.

Adrianna Gillman

A fast direct solver for boundary value problems on locally perturbed geometries

This talk presents a fast direct solver for boundary value problems where solutions are desired for geometries corresponding to local perturbations of the original geometry. Problems of this form arise in a variety of applications such as optimal design and flagella propelled movement simulations. The proposed solution technique utilizes a block linear system representation of the local perturbation which, thanks to a Woodbury formula, allows for the inverse of the matrix for the original system to be reused for all local perturbations. The cost of building the direct solver for the locally perturbed geometries grows linearly with the number of unknowns. Since the original system matrix is amenable to HSS, HBS, H-matrix, etc. solvers, the constant prefactor for the precomputation is much

smaller than building as direct solver from scratch or updating the hierarchical data structure for each new geometry. Numerical results will illustrate the performance of the new direct solver.

Christiane Helzel

Modelling and Simulation of the Sedimentation in Suspensions of Rod-Like Particles

Starting point of our considerations is a coupled system consisting of a kinetic equation coupled to a macroscopic Navier-Stokes equation describing the motion of a suspension of rigid rods under the influence of gravity. A reciprocal coupling leads to the formation of clusters: The buoyancy force creates a macroscopic velocity gradient that causes the microscopic particles to align so that their sedimentation reinforces the formation of clusters of higher particle density.

Since the coupled system is high-dimensional, we are interested in the derivation of simpler systems which describe the dynamics without resolving the kinetic equation.

We discuss two different approaches to obtain such systems. Furthermore, we discuss the numerical methods which were used to approximate the different mathematical models and show numerical results.

This is joint work with Athanasios E. Tzavaras from KAUST.

Bärbel Holm

The locally adapted patch finite element method for interface problems on triangular meshes

We present a locally adapted parametric finite element method for interface problems. For this adapted finite element method we show optimal convergence for elliptic interface problems with a discontinuous diffusion parameter. The method is based on the adaption of macro elements where a local basis represents the interface. The macro elements are independent of the interface and

can be cut by the interface. A macro element which is a triangle in the triangulation is divided into four subtriangles. On these subtriangles, the basis functions of the macro element are interpreted as linear functions. The position of the vertices of these subtriangles is determined by the location of the interface in the case a macro element is cut by the interface. Quadrature is performed on the subtriangles via transformations to a reference element. Due to the locality of the method, its use is well suited on distributed architectures.

Shilpa Khatri

Local analysis for close evaluation of layer potentials

Accurate evaluation of layer potentials near boundaries and interfaces are needed in many applications, including fluid-structure interaction problems and near-field scattering problems. A classical method to approximate the solution everywhere in the domain consists of using the same quadrature rule (Nyström method) used to solve the underlying boundary integral equation. This method is problematic for evaluations close to boundaries and interfaces. For a fixed number, N, of quadrature points, this method incurs a non-uniform error with O(1) errors in a boundary layer of thickness O(1/N). Using an asymptotic expansion of the associated kernel, we remove this O(1) error without having to use high-order Nyström methods. To demonstrate this method, we consider the interior and exterior Laplace problems.

Katharina Kormann

Geometric electromagnetic particle-in-cell methods

Numerical schemes that preserve the structure of the underlying kinetic equations can provide new insights into the long time behavior of fusion plasmas. In this talk we will present an electromagnetic particle-in-cell solver for the Vlasov-Maxwell equations that preserves at the discrete level the non-canonical Hamiltonian structure of the Vlasov-Maxwell equations. The Maxwell's equation are discretized by compatible spline finite elements that yield discrete differential operators that retain

properties like div curl = 0. Along with a classical particle discretization of the Vlasov equation, this yields a system of differential equations that has a Poisson structure, which is the non-canonical analog of a symplectic structure. We will discuss two time discretization schemes: an explicit Hamiltonian splitting that retains the Poisson structure and an energy-conserving semi-implict scheme.

Elisabeth Larsson

High-order meshfree radial basis function methods for PDEs

Radial basis function (RBF) based methods have many interesting properties such as being meshfree, providing ease of formulation in any number of dimensions, and having spectral convergence properties under certain conditions. There are also troublesome aspects such as severe ill-conditioning for basis functions that are nearly flat and high computational cost due to dense linear systems. In this talk, I will show how these issues can be overcome and how efficient RBF methods for partial differential equations can be constructed using a partition of unity approach.

Karin Leiderman

Toward a computational model of hemostasis

Hemostasis is the process by which a blood clot forms to prevent bleeding at a site of injury. The formation time, size, and structure of a clot depends, in part, on the local hemodynamics and the nature of the injury. Our group has previously developed computational models to study intravascular clot formation, a process confined to the interior of a single vessel. Here we present the first stage of an experimentally-validated, computational model of extravascular clot formation (hemostasis) in which blood through a single vessel initially escapes through a hole in the vessel wall and out a separate injury channel. This stage of the model consists of a system of partial differential equations that describes platelet aggregation and hemodynamics, solved via the finite element method. We also present results from the analogous, in vitro, microfluidic model. In both models, formation of a blood clot occludes the injury channel

and stops flow from escaping while blood in the main vessel retains its fluidity. We discuss the different biochemical and hemodynamic effects on clot formation using distinct geometries representing intra- and extravascular injuries.

Sookkyung Lim

Modeling hydrodynamic interaction of filamentous structures

Fluid-mechanical interaction of filamentous structures is ubiquitous in nature and occurs at a wide range of scales, for example, bacterial flagella, supercoiled DNA and sea cables. We present a general version of the immersed boundary (gIB) method combined with the unconstrained Kirchhoff rod theory, which allows us to study the hydrodynamic interaction of such filamentous structures. The Kirchhoff rod describes a filamentous structure as a "three-dimensional space curve" together with an orthonormal triad (material frame) at each point of the rod. The space curve represents the centerline of the rod and the triad indicates the amount of bend and twist. The elastic rod is immersed in a viscous fluid that is governed by the incompressible Navier-Stokes equations. The gIB method treats more general elasticity models that include both positional and rotational degrees of freedom. The positional degrees of freedom of the immersed structure move according to the local linear velocity of the fluid, whereas the rotational degrees of freedom move according to the local angular velocity. A couple of biological applications of the method will be presented.

Sandra May

Entropy stable spacetime discontinuous Galerkin methods for the compressible Navier-Stokes equations

We present entropy-stable methods for solving systems of hyperbolic conservation laws with physical diffusion terms. In particular we are interested in solving the compressible Navier-Stokes equations. Our methods are extensions of a spacetime discontinuous Galerkin method for solving systems of hyperbolic conservation laws [1].

In our extension to non-linear convection-diffusion equations we

mostly follow the original scheme for the treatment of the non-linear terms: we use entropy variables as degrees of freedom and use entropy stable numerical fluxes. For incorporating the diffusion terms, we use two variations of the interior penalty method resulting in the extensions ST-NIPG and ST-SIPG. Under suitable assumptions, we can show entropy stability for both schemes [2,3]. To avoid oscillations in the neighborhood of shocks when the physical diffusion cannot be sufficiently resolved, we keep the shock capturing terms of the original method and adjust them appropriately to account for the presence of the diffusion term [2,3].

In this talk, we will first give a short summary of the original method [1]. In the main part of the talk, we will present our extensions and discuss their entropy stability properties. We will conclude with numerical results for the two-dimensional compressible Navier-Stokes equations for several standard test cases.

[1] A. Hiltebrand and S. Mishra. Entropy stable shock capturing space-time discontinuous Galerkin schemes for systems of conservation laws. Numerische Mathematik, 126(1), 103--151, 2014.

[2] S. May. Spacetime discontinuous Galerkin methods for solving convection-diffusion systems. Accepted for publication by ESAIM Math. Model. Numer. Anal.. 2017.

[3] A. Hiltebrand and S. May. Entropy stable spacetime discontinuous Galerkin methods for the compressible Navier-Stokes equations. In preparation.

Michaela Mehlin

Multi-level Local Time-stepping Methods of Runge-Kutta type for Wave Equations

Wave type phenomena are common in many fields of science, such as seismology, acoustics and electromagnetics. The propagation of waves is often modeled by partial differential equations (PDEs), for which it is important to have accurate and efficient numerical solvers. In the presence of small geometric features or re-entrant corners in the spatial domain, locally refined meshes around the obstacles permit accurate simulations without introducing too many

spatial unknowns and are thus computationally efficient.

Local mesh refinement, however, significantly decreases the performance of explicit time-stepping methods, as the smallest mesh elements dictate the size of the time-step in the entire domain. To circumvent this problem we propose multi-level local time-stepping (MLTS) schemes. In the presence of meshes with several levels of refinement, MLTS methods allow for an appropriate time-step on each of the levels. The methods are based on explicit Runge-Kutta (RK) schemes and an extension of the LTS-RK methods, their 2-level counterpart. They retain the explicitness and the one-step nature of the underlying RK method and thus require no starting procedure and facilitate adaptivity in time. We show that the novel schemes keep the accuracy of the underlying RK scheme and present numerical results that illustrate the versatility of the approach.

Maya Neytcheva

Advances in solving discrete PDE-constrained optimization problems

Many inverse and parameter estimation problems can be formulated as PDE-constrained optimization problems, where the constraint is determined by a scalar or vector partial differential equation. Very often, when discretized, such problems are large scale and require fast, efficient and robust iterative solution methods.

In recent years much research effort has been devoted to constructing efficient preconditioners for solving discrete algebraic systems arising from various constrained optimization problems. The matrices in the so-obtained linear systems of equations possess a specific block structure and, depending on the target problem, can be definite or indefinite. Various authors have worked on how to precondition these matrices, applying the existing knowledge and the experience of general block-preconditioners for definite and indefinite systems, arising from the discretization of scalar or vector (systems of) PDEs.

In this talk, examples of PDE-constrained optimization problems will be shown, with various types of control. We briefly survey some well-established and novel preconditioning strategies, illustrated for various classes of PDE-constrained optimization problems, e.g., when

the PDE-constraint is given by the Poisson equation, by a convection-diffusion equation, by the stationary Stokes equations and more.

We present some comparative results of the performance of the corresponding preconditioned solvers, both in terms of iterations and in terms of computing time. For the discretization in space (the Finite Element method), the solution methods and the pre-conditioners are implemented using available toolboxes from open source scientific libraries - deal.ii and Trilinos.

In this framework, very often the aricing algebraic problems are nonlinear. An idea how to diminish the computational effort in the nonlinear case will be given too.

Difficulties and problems to be addressed in future research will also be mentioned.

Nilima Nigam

Regularizations of the Dirac delta distribution, and applications.'

The need to approximate singular sources is widespread in numerical analysis. In this talk, we present a framework for constructing approximations of the Dirac delta distribution, and study their convergence in suitable topologies. This in turn allows us to examine the consistency error incurred in their use while numerically solving PDEs. We present numerical experiments in which these ideas are illustrated. This work was inspired by previous works by Tornberg and Enquist, and is joint with Bamdad Hosseini and John Stockie.

Anna Nissen

Efficient Uncertainty Propagation of Multiple-point Statistics in Porous Media

Many subsurface reservoirs of interest in practical applications such as CO2 storage, petroleum engineering or thermal energy extraction are highly heterogeneous with complex geological structures such as channels, fractures and faults. In addition, lack of experimental data

as well as the infeasibility to represent all structural features relevant to describing flow and transport makes mathematical models of these reservoirs subject to significant geological uncertainty. A meaningful mathematical model should therefore be able to accurately represent the most important sources of uncertainty. In addition, stochastic methods for flow and transport simulations of channelized reservoirs must be able to represent non-smooth material properties, such as sharp permeability transitions between channels and surrounding matrix. Traditional two-point statistics methods perform poorly in representing these features, but methods relying on multiple-point statistics can be used to represent channels within a stochastic framework.

In this work we consider a multiple-point statistics framework using kernel transformations to accurately represent structured porous media. Training images of heterogeneous media or empirical data can be used as a basis for the stochastic representation of permeability. Stochastic quadrature rules specifically tailored to the data are then constructed using the generalized polynomial chaos method based on empirical moments. We apply the uncertainty quantification framework to a setting where heterogeneity and uncertainty are present and crucial for the outcome: a vertical equilibrium model of CO2 migration. CO2 is injected into a brine-filled heterogeneous (channelized) reservoir, in which it migrates through gravity and background flow over many years. The CO2 migration is described by a nonlinear conservation law, discretized in space with a finite volume method and a Godunov flux function for robust shock-capturing.

Sarah Olson

Modeling sperm motility using the method of regularized Stokeslets

The method of regularized Stokeslets (MRS) is a Lagrangian numerical algorithm that utilizes regularized fundamental solutions to obtain the flow at and around microorganisms such as sperm. The regularization of point forces (and possibly point torques) is done with a radially symmetric blob function of infinite support. This is a common method to study swimmers at zero Reynolds number where the Stokeslet is the fundamental solution corresponding to the kernel of the single layer potential. In this talk, we will show how to derive

the regularized fundamental solutions as well as show results for sperm motility in 2d and 3d, highlighting the importance of stiffness parameters and coupling to chemical concentrations. Time permitting, we will discuss the efficient simulation of a large number of swimmers in free space using an implementation of the kernel-independent fast multipole method (FMM) for radial basis functions.

Jennifer K. Ryan

1D Smoothness-Increasing Accuracy Conserving Filters for Multi-Dimensional Data: The importance of divided differences and rotation angle

Over the past few decades there has been a strong effort towards the development of Smoothness-Increasing Accuracy-Conserving (SIAC) filters for Discontinuous Galerkin (DG) methods, designed to increase the smoothness and improve the convergence rate of the DG solution through this post-processor. These advantages can be exploited during flow visualization, for example by applying the SIAC filter to the DG data before streamline computations. However, introducing these filters in engineering applications can be challenging since a tensor product filter grows in support size as the field dimension increases, becoming computationally expensive.
As an alternative, Walfisch et al. proposed a univariate filter implemented along the streamline curves. Until now, this technique remained a numerical experiment. In this talk we introduce the SIAC line filter and explore how the orientation, structure and filter size affect the order of accuracy and global errors. We present theoretical error estimates based on divided differences that show how line filtering preserves the properties of traditional tensor product filtering, including smoothness and improvement in the convergence rate, given an appropriate rotation. Furthermore, numerical experiments are included, exhibiting how these filters achieve the same accuracy at significantly lower computational costs, becoming an attractive tool for the scientific visualization community.

Chiara Sorgentone

A highly accurate boundary integral equation method for 3D surfactant-covered drops

Surfactants (surface active agents) are compounds that lower the surface tension between liquids; they are widely used in engineering applications, in pharmaceuticals, foods and petroleum industries. We will consider viscous drops immersed in a different viscous fluid and covered by an insoluble surfactant. At this small scale the interface dynamics become of increased importance, viscous forces dominate and inertial effects are often negligible. Considering Stokes flow, a numerical method based on a boundary integral formulation is presented. The method is able to simulate 3D drops with different viscosities and close interactions, automatically controlling the time step size and maintaining high accuracy also when strong deformations of the drops surfaces appear. A very accurate representation of both the drop surfaces and the surfactant concentration is given by a spherical harmonics expansion, which results to have several advantages for the overall algorithm. A new reparameterization method is introduced to maintain a high-quality representation of the drops also under deformation, specialized quadrature methods for singular and nearly singular integrals that appear in the formulation are evoked and the adaptive time stepping scheme for the coupled drop and surfactant evolution is designed with special attention to the implicit treatment of the surfactant diffusion.

Lina von Sydow

Efficient and accurate pricing of options

In this talk we will discuss numerical pricing of options issued on a basket of underlying assets or assets with stochastic volatility. We will present the challenges with such problems and present a method based on radial basis functions generated finite differences that is well suited for this purpose. We will also present a benchmarking project where a large number of methods to numerically price options are compared http://www.it.uu.se/research/scientific_computing/project/compfin/benchop. A first paper has been published and there is ongoing work on the more challenging problems described in this talk.

Mechthild Thalhammer

Favourable time integration methods for non-autonomous evolution equations

In this talk, I shall introduce the class of commutator-free quasi-Magnus exponential integrators for non-autonomous linear evolution equations and identify different areas of application.

Commutator-free quasi-Magnus exponential integrators are (formally) given by a composition of several exponentials that comprise certain linear combinations of the values of the defining operator at specified nodes. Avoiding the evaluation of commutators, they provide a favourable alternative to standard Magnus integrators.

Non-autonomous linear evolution equations also arise as a part of more complex problems, for instance in connection with nonlinear evolution equations of the form $u'(t) = A(t)\,u(t) + B(u(t))$. A natural approach is thus to apply commutator-free quasi-Magnus exponential integrators combined with operator splitting methods. Relevant applications include Schrödinger equations with space-time-dependent potential describing Bose-Einstein condensation or diffusion-reaction systems modelling pattern formation.

Sara Zahedi

A High Order Space-Time Cut Finite Element Method for PDEs on Evolving Surfaces

I will present a high order space-time cut finite element method for solving a time-dependent convection-diffusion equation modeling the evolution of insoluble surfactants on the interface separating two immiscible fluids. The method avoids remeshing procedures as the interface is evolving and is simple to implement.

In Cut Finite Element Methods (CutFEM) the moving domain where the PDE has to be solved on is embedded in a domain with a fixed background mesh equipped with a standard finite element space and then one uses the restriction of the basis functions to the so called active mesh where the bilinear forms associated with the weak

formulation are evaluated. Stabilization terms are added in the weak form to ensure well-conditioned linear systems independently of the position of the geometry relative to the background mesh.

I will present stabilization terms that control the condition number of the resulting linear systems also when high order elements are used.