FVCA7

The International Symposium on Finite Volumes for Complex Applications VII

Berlin, Juni 15 - 20, 2014

www.wias-berlin.de/workshops/fvca7

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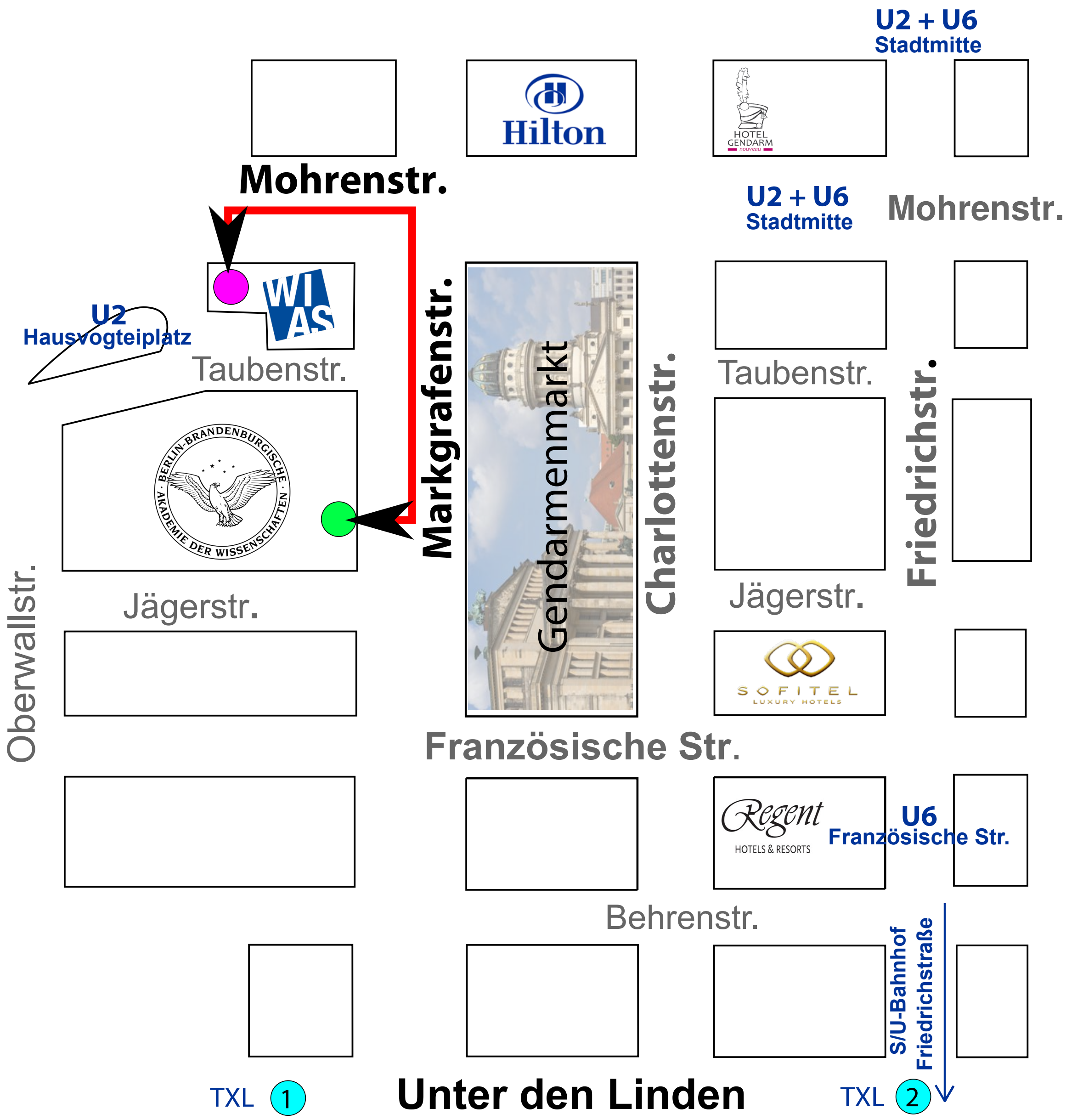
1 Map WIAS-BBAW



Bus Stop TXL between Tegel/Alexanderplatz:

① Staatsoper

② Unter den Linden/Friedrichstraße

● **Conference in the BBAW (Akademie of Sciences)**

● **WIAS Registration**

2 Scope

The finite volume method in its various variants is a space discretization technique for partial differential equations based on the fundamental physical principle of conservation. It has been used successfully in many applications including fluid dynamics, magnetohydrodynamics, structural analysis, nuclear physics, and semiconductor theory. Recent decades have brought significant success in the theoretical understanding of the method. Many finite volume methods preserve further qualitative or asymptotic properties including maximum principles, dissipativity, monotone decay of the free energy, or asymptotic stability.

Due to these properties, finite volume methods belong to the wider class of compatible discretization methods, which preserve qualitative properties of continuous problems at the discrete level. This structural approach to the discretization of partial differential equations becomes particularly important for multiphysics and multiscale applications.

The goal of the symposium is to bring together mathematicians, physicists, and engineers interested in physically motivated discretizations. Contributions to the further advancement of the theoretical understanding of suitable finite volume, finite element, discontinuous Galerkin and other discretization schemes, and the exploration of new application fields for them are welcome.

Main Focus

- Preservation of physical properties on the discrete level
- Physically consistent coupling between discretizations for different processes
- Convergence, stability, and error analysis
- Connections to other discretization methods
- Relationship between grids and discretization schemes
- Complex geometries and adaptivity
- Shock waves and other flow discontinuities
- New and existing schemes and their limitations
- Bottlenecks in the solution of large scale problems
- Applications
  - Atmosphere and ocean modeling
  - Chemical engineering and combustion
  - Energy generation and storage
  - Semiconductors and electrochemistry
  - Porous media

3 General Information

Registration	Start:	June 15, 19:00
	Location:	WIAS, Mohrenstr. 39, 10117 Berlin, Erhard-Schmidt-Hörsaal
Scientific Program	Start:	June 16, 08:00
	End:	June 20, 17:00
	Location:	Leibiz Hall, Berlin-Brandenburg Academy of Science and Humanities (BBAW), Markgrafenstr. 38, 10117 Berlin [*see page 5*]
Roof Top Reception	Start:	June 16, 18:00
	Location:	BBAW on the 5th floor - Einstein Hall with the Winter Garden [*see page 5*]
River Cruise	Start:	June 18, 16:00 (Märkisches Ufer) [*see page 11*]
	End:	June 18, 18:00 (Dovebrücke) [*see page 13*]

Organizing Committee

Peter Bastian (Heidelberg), Robert Eymard (Paris), Jürgen Fuhrmann (Berlin), Jiří Fürst (Prague), Annegret Glitzky (Berlin), Volker John (Berlin), Rupert Klein (Berlin), Alexander Linke (Berlin), Mario Ohlberger (Münster), Christian Rohde (Stuttgart), Jörn Sesterhenn (Berlin)

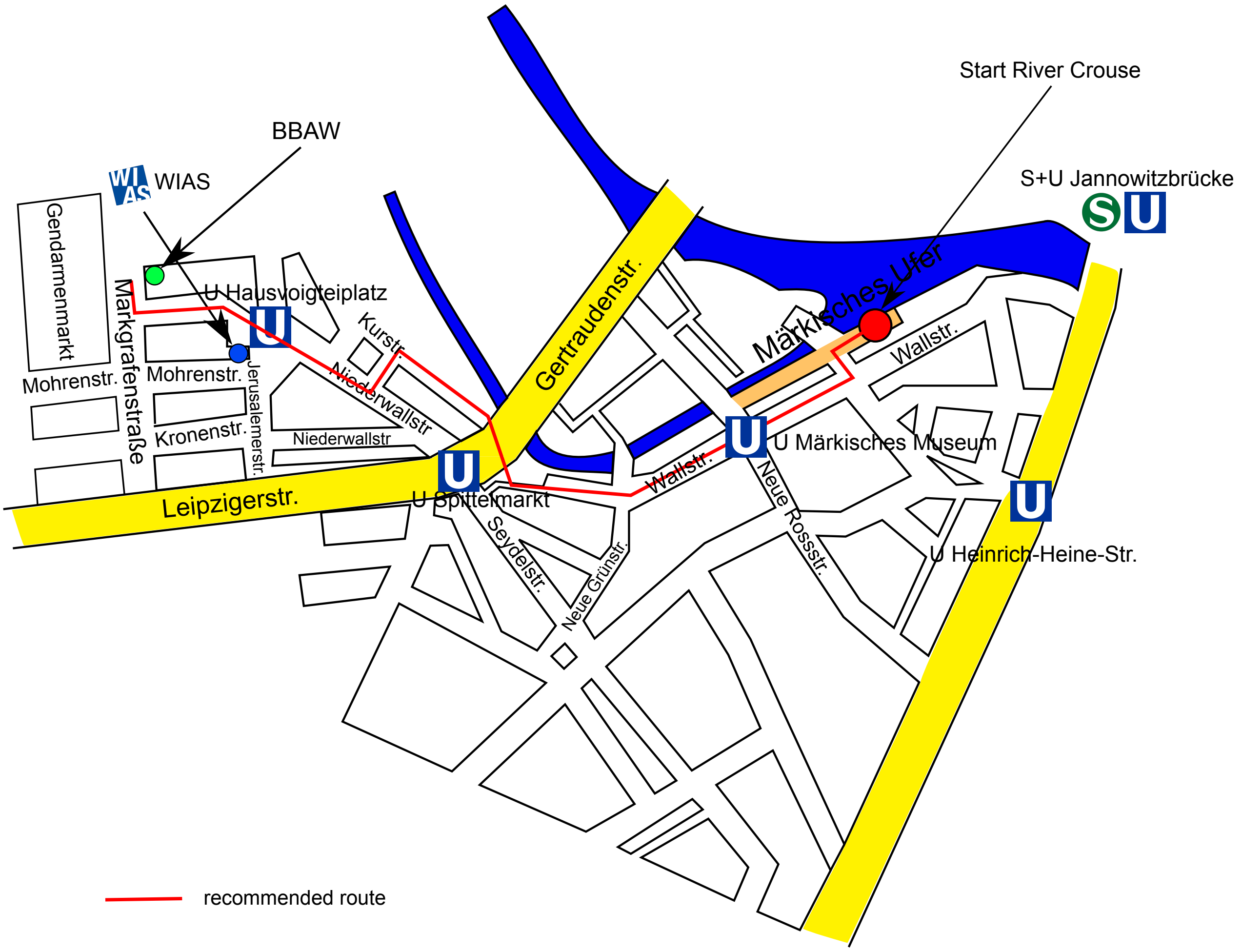
Support of the following entities is gratefully acknowledged:

- Deutsche Forschungsgemeinschaft (DFG)
- DFG MetStröm (Priority Program)
- University of Stuttgart, Stuttgart Research Centre for Simulation Technology (SRC SimTech)
- Czech Technical University Prague (CTU)
- Weierstraß-Institut für Angewandte Analysis und Stochastik Berlin (WIAS)

Hints

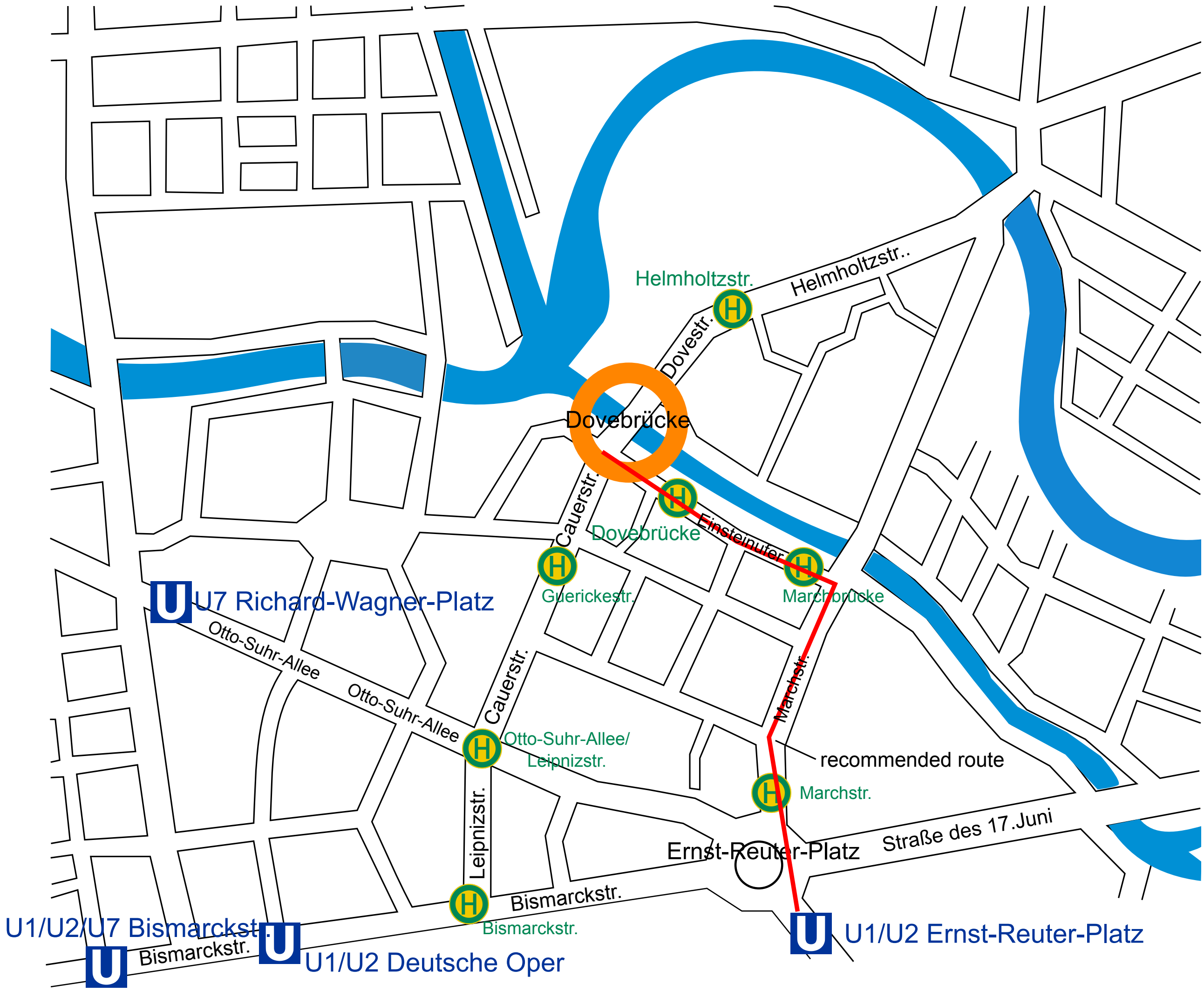
- The local organizers and all contact persons wear yellow badges.
- WLAN available at 3 conference rooms and lecture hall: see information at registration desk.
- On Monday all the conference rooms and the lecture hall open 7:30.
- From Tuesday to Friday the venues open at 8:30.

4 Start of River Cruise



On Wednesday June 18, 15:45 we will board the “Spree Comtess” navigated by **captain Ratajczak** for a two hour river cruise through the center of Berlin. **Ms. Semabinia** will be on board and act as a city guide. We will walk to the starting point at Märkisches Ufer after the photo shooting (distance approximately 2km, guided by the WIAS colleagues with the yellow badges). The cruise will end around 18:00 at Dovestraße with good access to the U2 underground for the way back.

5 End of River Cruise



6 Programme

Monday, 16.06.2014	
08:00 – 09:00	**Registration**
09:00 – 09:20	**Opening** Sprekels, Jürgen (Director WIAS)
09:20 – 10:00	**Dumbser, Michael (Italia)** High order one-step AMR and ALE methods for hyperbolic PDE
10:00 – 10:20	**Giesselmann, Jan (Germany)** On a posteriori error analysis of DG schemes approximating hyperbolic conservation laws
10:20 – 10:40	**Franck, Emmanuel (Germany)** Modified finite volume nodal scheme for Euler equations with gravity and friction
10:40 – 11:20	Coffee break
11:20 – 11:40	**Arpaia, Luca (France)** An ALE formulation for explicit Runge-Kutta residual distribution
11:40 – 12:00	**von Larcher, Thomas (Germany)** Towards a stochastic closure approach for large eddy simulation
12:00 – 12:20	**Sabat, Macole (France)** Comparison of realizable schemes for the Eulerian simulation of disperse phase flows
12:20 – 12:40	**Zaza, Chady (France)** Comparison of cell-centered and staggered pressure-correction schemes for all-Mach flows
12:40 – 14:20	Lunch
14:20 – 15:00	**Helluy, Philippe (France)** Interpolated pressure laws in two-fluid simulations and hyperbolicity
15:00 – 15:20	**Munz, Claus-Dieter (Germany)** A combined finite volume discontinuous Galerkin approach for the sharp-interface tracking in multi-phase flow
15:20 – 15:40	**Aguillon, Nina (France)** Numerical simulations of a fluid-particle coupling
15:40 – 16:20	Coffee break
16:20 – 16:40	**Feistauer, Miloslav (Czech Republic)** Numerical solution of fluid-structure interaction by the space-time discontinuous Galerkin method
16:40 – 17:00	**Berndt, Phillip (Germany)** On the use of the HLL-Scheme for the simulation of the multi-species Euler equations
17:00 – 17:20	**Dallet, Sophie (France)** An asymptotic preserving scheme for the barotropic Baer-Nunziato model
17:20 – 17:40	**Martin, Xavier (France)** A simple finite volume approach to compute flows in variable cross-section ducts
17:40 – 18:00	**Zenk, Markus (Germany)** A well-balanced scheme for the Euler equation with a gravitational potential
19:00	Roof Top Reception

Tuesday, 17.06.2014	
09:00 – 09:20	**Linke, Alexander (Germany)** Optimal and pressure-independent L2 velocity error estimates for a modified Crouzeix-Raviart element with BDM reconstructions
09:20 – 09:40	**Müller, Thomas (Germany)** Estimating the geometric error of finite volume schemes for conservation laws on surfaces for generic numerical flux functions
09:40 – 10:00	**Köppel, Markus (Germany)** Stochastic modeling for heterogeneous two-phase flow
10:00 – 10:20	**Armiti-Juber, Alaa (Germany)** Almost parallel flows in porous media
10:20 – 11:00	Coffee break
11:00 – 11:20	**Kumar, Nikhil (The Netherlands)** A new discretization method for the convective terms in the incompressible Navier-Stokes equations
11:20 – 11:40	**Feron, Pierre (France)** Gradient schemes for Stokes problem
11:40 – 12:00	**Krell, Stella (France)** A DDFV scheme for incompressible Navier–Stokes equations with variable density
12:00 – 12:20	**Saleh, Khaled (France)** A staggered scheme with non-conforming refinement for the Navier-Stokes equations
12:20 – 14:00	Lunch
14:00 – 14:40	**Chainais-Hillairet, Claire (France)** Entropy method and asymptotic behaviours of finite volume schemes
14:40 – 15:00	**Auphan, Thomas (France)** Asymptotic-preserving methods for an anisotropic model of electrical potential in a tokamak
15:00 – 15:20	**Leroy, Thomas (France)** A well-balanced scheme for a transport equation with varying velocity arising in relativistic transfer equation
15:20 – 16:00	Coffee break
16:00 – 17:00	**Poster Presentation**
17:00 – 19:00	**Poster I**

Poster I – Tuesday, 17.06.2014

Anthonissen, Martijn (The Netherlands)
The complete flux scheme in cylindrical coordinates

Bacigaluppi, Paola (France)
A 1D stabilized finite element model for non-hydrostatic wave breaking and run-up

Balažovjech, Martin (Slovakia)
Semi-implicit second order accurate finite volume method for advection-diffusion level set equation

Bradji, Abdallah (Algeria)
A note on a new second order approximation based on a low–order finite volume scheme for the wave equation in one space dimension

Brouwer, Jens (Germany)
Conservative finite differences as an alternative to finite volume for compressible flows

Droniou, Jérôme (Australia)
A uniformly converging scheme for fractal conservation laws

Fiebach, André (Germany)
Uniform estimate of the relative free energy by the dissipation rate for finite volume discretized reaction-diffusion systems

Ferrand, Martin (France)
An anisotropic diffusion finite volume algorithm using a small stencil

Handlovičová (Slovakia)
Semi-implicit alternating discrete duality finite volume scheme for curvature driven level set equation

Hartung, Niklas (France)
An efficient implementation of a CeVeFE DDFV scheme on cartesian grids and an application in image processing

Hérard, Jean-Marc (France)
Some applications of a two-fluid model

Lipnikov, Konstantin (USA)
Mimetic finite difference schemes with the conditional maximum principle for diffusion problems

Masson, Roland (France)
High performance computing linear algorithms for two-phase flow in porous media

Mathis, Hélène (France)
Modeling phase transition and metastable phases

Merdon, Christian (Germany)
Coupling of fluid flow and solute transport using a divergence-free reconstruction of the Crouzeix-Raviart element

Neusius, David (Germany)
On boundary approximation for simulation of granular flow

Ohlberger, Mario (Germany)

A-posteriori error estimates for the localized reduced basis multi-scale method

Olivier, Hurisse (France)
Application of a two-fluid model to simulate the heating of two-phase flows

Strachota, Pavel (Czech Republic)
A quasi-1D model of biomass co-firing in a circulating fluidized bed boiler

Turpault, Rodolphe (France)
An asymptotic-preserving scheme for systems of conservation laws with source terms on 2D unstructured meshes

Vidovic, Dragan (Serbia)
Piecewise linear transformation in diffusive flux discretizations

Zhang, Yumeng (France)
Coupling of a two phase gas liquid compositional 3D Darcy flow with a 1D compositional free gas flow

Wednesday, 18.06.2014	
09:00 – 09:40	**Mikula, Karol (Slovakia)** Finite volume methods in image processing
09:40 – 10:00	**Remesikova, Mariana (Slovakia)** 3D Lagrangian segmentation with simultaneous mesh adjustment
10:00 – 10:20	**Kriváá, Zuzana (Slovakia)** Gradient evaluation on a quadtree based finite volume grid
10:20 – 11:00	Coffee break
11:00 – 11:20	**Cancès, Clément (France)** Entropy-diminishing CVFE scheme for solving anisotropic degenerate diffusion equations
11:20 – 11:40	**Droniou, Jérôme (Australia)** Uniform-in-time convergence of numerical schemes for Richards' and Stefans' models
11:40 – 12:00	**Chernyshenko, Alexey (Russia)** A finite volume scheme with the discrete maximum principle for diffusion equations on polyhedral meshes
12:00 – 12:20	**Gao, Zhi-Ming (China)** Interpolation-based second-order monotone finite volume scheme for diffusion equations on general meshes
12:20 – 14:00	Lunch
14:00 – 14:20	**Ortleb, Sigrun (Germany)** Positivity preserving implicit and partially implicit time integration methods in the context of the DG scheme applied to shallow water flows
14:20 – 14:40	**Gunawan, Putu Harry (France)** An explicit staggered finite volume scheme for the shallow water equations
14:40 – 15:00	**Vater, Stefan (Germany)** Well-balanced inundation modeling for shallow-water flows with discontniuous Galerkin schemes
15:00 – 15:10	Conference photo
16:00 – 18:00	River Cruise

Thursday, 19.06.2014	
09:00 – 09:40	**Almgren, Ann (USA)** Low mach number modeling of stratified flows
09:40 – 10:00	**Waidmann, Matthias (Germany)** A conservative coupling of level-set, volume-of-fluid and other conserved quantities
10:00 – 10:20	**Minjeaud, Sebastian (France)** Consistency analysis of a 1D finite volume scheme for barotropic Euler models
10:20 – 11:00	Coffee break
11:00 – 11:20	**Brenner, Konstantin (France)** Vertex approximate gradient scheme for hybrid dimensional two-phase Darcy flows in fractured porous media
11:20 – 11:40	**Guichard, Cindy (France)** Gradient discretization of hybrid dimensional Darcy flows in fractured porous media
11:40 – 12:00	**Nikitin, Kirill (Russia)** Nonlinear monotone FV scheme for radionuclide geomigration and multiphase flows models
12:00 – 12:20	**Rybak, Iryna (Germany)** Coupling free flow and porous medium flow systems using sharp interface and transition region concepts
12:20 – 14:00	Lunch
14:00 – 14:40	**Bochev, Pavel (USA)** A new parameter-free stabilization approach for advection-diffusion equations based on H(curl)-lifting of multi-scale fluxes
14:40 – 15:00	**Colin, Pierre-Louis (France)** Convergence of a finite volume scheme for a corrosion model
15:00 – 15:20	**Knabner, Peter (Germany)** FV stabilizations of FE discretizations of advection-diffusion problems
15:20 – 16:00	Coffee break
16:00 – 17:00	**Poster Presentation**
17:00 – 19:00	**Poster II**

Poster II – Thursday, 19.06.2017

Baron, Vincent (France)
Adaptive time discretization and linearization based on a posteriori estimates for the Richards equation

Bradji, Abdallah (Algeria)
Note on the convergence of a finite volume scheme using a general nonconforming mesh for an oblique derivative boundary value problem

Seaid, Mohammed (UK)
A finite volume method for large-eddy simulation of shallow-water equations

Fuhrmann, Jürgen (Germany)
Activity based finite volume methods for generalised Nernst-Planck-Poisson systems

Fürst, Jiří (Czech Republic)
Numerical simulation of flow in a meridional plane of multistage turbine

Gasc, Thibault (France)
Suitable formulations of Lagrange remap finite volume schemes for manycore / GPU architectures

Keslerová, Radka (Czech Republic)
Numerical modelling of viscous and viscoelastic fluids flow in the channel with t-junction

Le Potier, Christophe (France)
Convergence of a nonlinear scheme for anisotropic diffusion equations

Mallem, Khadidja (France)
Convergence of the MAC scheme for the steady-state incompressible Navier-Stokes equations on non-uniform grids

Maltese, David (France)
Discrete relative entropy for the compressible Stokes problem

Meltz, Bertrand-Jylien (France)
An arbitrary space-time high-order finite volume scheme for gas dynamics equations in curvilinear coordinates on polar meshes

Michel-Dansac, Victor (France)
A conservative well-balanced hybrid SPH scheme for the shallow-water model

Mohamed, Gazibo Karimou (France)
Convergence of finite volume scheme for degenerate parabolic problem with zero flux boundary condition

Nabet, Flore (France)
Finite volume analysis for the Cahn-Hilliard equation with dynamic boundary conditions

Ndjinga, Michael (France)
Weak convergence of nonlinear finite volume schemes for linear hyperbolic systems

Nguyen, Thi-Phuong-Kieu (France)
Numerical simulation of an incompressible two-fluid model

Printsypar, Galina (Kingdom of Saudi Arabia)
MPFA algorithm for solving Stokes–Brinkman equations on quadrilateral grids

Rave, Stephan (Germany)
A model reduction framework for efficient simulation of Li-ion batteries

Saad, Mazen (France)
Convergence analysis of a FV-FE scheme for partially miscible two-phase flow in anisotropic porous media

Sonntag, Matthias (Germany)
Shock capturing for discontinuous Galerkin methods using finite volume sub-cells

Ung, Philippe (France)
A simple well-balanced, positive and entropy-satisfying numerical scheme for the shallow-water system

Vu Do, Huy Cuong (France)
A gradient scheme for the discretization of Richards equation

Friday, 20.06.2014	
09:00 – 09:40	**Després, Bruno (France)** Finite-Volumes schemes with corner based fluxes: A journey from Lagrangian fluid dynamics to heat equation
09:40 – 10:00	**Crestetto, Anais (France)** Asymptotic-preserving scheme based on a finite volume/particle-in-cell coupling for Boltzmann-BGK-like equations in the diffusion scaling
10:00 – 10:20	**Bernard, Florian (France)** Simulation of diluted flow regimes in presence of unsteady boundaries
10:20 – 11:00	Coffee break
11:00 – 11:20	**Bessemoulin-Chatard, Marianne (France)** Monotone combined finite volume-finite element scheme for a bone healing model
11:20 – 11:40	**May, Sandra (Switzerland)** A mixed explicit implicit time stepping scheme for Cartesian embedded boundary meshes
11:40 – 12:00	**Alnashri, Yahya (Australia)** Gradient schemes for an obstacle problem
12:00 – 12:20	**Erath, Christoph (Austria)** Comparison of two couplings of the finite volume method and the boundary element method
12:20 – 14:00	Lunch
14:00 – 14:20	**Bradji, Abdallah (Algeria)** A new finite volume scheme for a linear Schroedinger evolution equation
14:20 – 14:40	**Girke, Stefan (Germany)** Efficient parallel simulation of atherosclerotic plaque formation using higher order discontinuous Galerkin schemes
14:40 – 15:00	**ten Thije Boonkkamp, Jan (The Netherlands)** Numerical dissipation and dispersion of the homogeneous and complete flux schemes
15:00	Closing

7 Abstracts

7.1 INVITED SPEAKERS

Low mach number modeling of stratified flows

A. Almgren, J. Bell, A. Nonaka (Lawrence Berkeley National Laboratory, USA)
M. Zingale (Stony Brook University, USA)

Low Mach number equation sets approximate the equations of motion of a compressible fluid by filtering out the sound waves, which allows the system to evolve on the advective rather than the acoustic time scale. Depending on the degree of approximation, low Mach number models retain some subset of possible compressible effects. In this paper we give an overview of low Mach number methods for modeling stratified flows arising in astrophysics and atmospheric science as well as low Mach number reacting flows. We discuss how elements from the different fields are combined to form MAESTRO, a code for modeling low Mach number stratified flows with general equations of state, reactions and time-varying stratification.

A new parameter-free stabilization approach for advection-diffusion equations based on H(curl)-lifting of multi-scale fluxes

P. Bochev (Sandia National Laboratories, USA)

We present a family of stabilized control volume (CV) and finite element (FE) methods for advection-diffusion equations based on a new, multi-scale approximation of the total flux. The latter is defined by an H(curl) lifting of one-dimensional edge fluxes into the mesh elements by using suitable curl-conforming elements. These fluxes are obtained from analytic solutions of the governing equations restricted to the mesh edges. In so doing we obtain a multi-scale approximation of the flux that is stable in the advective limit and does not involve any tunable mesh-dependent stabilization parameters. In the lowest-order case the edge fluxes are obtained by a procedure similar to the Scharfetter-Gummel unwinding and so, resulting CV methods can be viewed as multidimensional extensions of this classical scheme to arbitrary unstructured grids. This feature sets our CV formulations apart from other Scharfetter–Gummel extensions to multiple dimensions, which require control volumes that are topologically dual to the primal grid. In the higher-order case the edge fluxes are defined on suitable mesh segments comprising multiple edges by a procedure that "bootstraps" the classical Scharfetter-Gummel approach. Accordingly we perform the H(curl) lifting by using edge elements that match the accuracy of the edge fluxes and whose degrees of freedom are collocated with their positions. We extend these ideas to FE formulations by using the multi-scale flux to define a stabilizing H(curl) diffusion kernel. Symmetrization of this kernel yields an artificial diffusion term that can be used to stabilize a standard Galerkin formulation of the governing equations without requiring tunable mesh-dependent stabilization parameters. To conclude the talk we will briefly touch upon the implementation of these schemes in Sandia's semiconductor device modeling code CHARON and present numerical results for a suite of standard advection tests, and simulations of a PN diode and an n-channel MOSFET device, which demonstrate the performance of the methods for a fully coupled drift-diffusion system. This is joint work with K. Peterson, M. Perego and X. Gao.

Entropy method and asymptotic behaviours of finite volume schemes

C. Chainais-Hillairet (UniversitéLille 1, France)

When deriving a numerical scheme for a system of PDEs coming for instance from physics or engineering, it is crucial to propose a scheme which preserves the asymptotic behavior of the continuous system, with respect to time as with respect to some parameters. In this paper, we want to show how the entropy method can be applied to some finite volume schemes and permits to show that some schemes are asymptotic preserving. We focus on two problems: the nonlinear diffusion equation (long time behavior) and the drift-diffusion system (long time behavior and quasi-neutral limit). Some results have been obtained in collaboration with A. Jüngel and S. Schuchnigg [1] and the others with M. Bessemoulin-Chatard and M.-H. Vignal [2].

Rererences:

[1] Chainais-Hillairet, C., Jüngel, A. and Schuchnigg, S.: Entropy-dissipative discretization of nonlinear diffusion equations and discrete beckner inequalities, *submitted for publication*
URL http://hal.archives-ouvertes.fr/hal-00924282.

[2] Bessemoulin-Chatard, M., Chainais-Hillairet, C. and Vignal, M.H.: Study of a finite volume scheme for the drift-diffusion system. asymptotic behavior in the quasi-neutral limit, *submitted for publication*
URL http://hal.archives-ouvertes.fr/hal-00801912.

Finite-Volumes schemes with corner based fluxes: A journey from Lagrangian fluid dynamics to heat equation

B. Després (LJLL/UPMC, France)

Cell-centered Finite Volume schemes with corner-based fluxes for Lagrangian fluid dynamics received a strong impetus since 2000' . Indeed it has been understood that corner-based fluxes are the only solution so far to obtain compatibility with mesh displacement and the entropy condition. In a first part I will review some fundamental properties of this family of methods. In a second part more recent developments will be presented: on contacts problems, preservation of the angular momentum and the link with the F.V. discretization of the heat equation.

High order one-step AMR and ALE methods for hyperbolic PDE

M. Dumbser (University of Trento, Italy, Italia)

In this talk a unified family of high order accurate finite volume and discontinuous Galerkin schemes is presented on moving unstructured and adaptive Cartesian meshes for the solution of conservative and non-conservative hyperbolic partial differential equations.

The $P_N P_M$ approach adopted here uses piecewise polynomials u_h of degree N to represent the data in each cell. For the computation of fluxes and source terms, another set of piecewise polynomials w_h of degree $M \geq N$ is used, which is computed from the underlying polynomials u_h using a reconstruction or recovery operator. The $P_N P_M$ method contains classical high order finite volume schemes $(N = 0)$ and high order discontinuous Galerkin (DG) finite element methods $(N = M)$ as two special cases of a more general class of numerical schemes. The schemes are derived in general ALE form so that Eulerian schemes on fixed meshes and Lagrangian schemes on moving meshes can be recovered as special cases of the ALE formulation. Furthermore, the method can also be naturally implemented on space-time adaptive Cartesian grids (AMR), together with time-accurate local time stepping (LTS). To assure the robustness of the method at discontinuities, either a classical high order nonlinear WENO reconstruction is performed, or the more recent and promising *a-posteriori* MOOD framework is adopted. The time integration is carried out in one single step using a high order accurate local space-time Galerkin predictor that is also able to deal with stiff source terms.

Applications are shown for the compressible Euler and Navier–Stokes equations, for the MHD equations and for the Baer–Nunziato model of compressible multi-phase flows.

References:

[1] M. Dumbser, D.S. Balsara, E.F. Toro and C.D. Munz: A Unified Framework for the Construction of One-Step Finite-Volume and Discontinuous Galerkin Schemes on Unstructured Meshes, *Journal of Computational Physics,* **227**:8209–8253, 2008.

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[6] M. Dumbser, O. Zanotti, A. Hidalgo and D.S. Balsara: ADER-WENO Finite Volume Schemes with Space-Time Adaptive Mesh Refinement, *Journal of Computational Physics,* **248**:257–286, 2013.

Interpolated pressure laws in two-fluid simulations and hyperbolicity

Ph. Helluy, J. Jung (University of Strasbourg, France)

We consider a two-fluid compressible flow. Each fluid obeys a stiffened gas pressure law. The continuous model is well defined without considering mixture regions. However, for numerical applications it is often necessary to consider artificial mixtures, because the two-fluid interface is diffused by the numerical scheme. We show that classic pressure law interpolations lead to non-convex hyperbolicity domain and failure of well-known numerical schemes. We propose a physically relevant pressure law interpolation construction and show that it leads to a necessary modification of the pure phase pressure laws. We also propose a numerical scheme that permits to approximate the stiffened gas mode.

Finite volume methods in image processing

K. Mikula (Slovak University of Technology, Slovakia)

In this talk we discuss the finite volume methods developed for the image processing applications. Due to piecewise constant character of the image data on pixels/voxels, the finite volume approximation is the most natural one. It also allows rigorous analysis of numerical schemes with respect to convergence to weak solutions for various nonlinear advection-diffusion models used in image filtering, segmentation, object detection and tracking. The semi-implicit in time finite volume discretization of nonlinear equations gives robust (stable and efficient) numerical algorithms which can be naturally parallelized and used for large-scale problems like processing of 3D time image sequences. We will discuss such application, the processing of 3D videos coming from laser scanning microscopy of early stages of Zebrafish embryogenesis.

High-resolution finite volume schemes for computing entropy measure valued solutions of hyperbolic conservation laws

S. Mishra (ETH Zürich, Switzerland)

The concept of entropy measure valued solutions was introduced by DiPerna in the mid 80s as a theoretical tool to study systems of conservation laws. Recent numerical evidence as well as analytical results suggest that entropy measure valued solutions are an appropriate solution framework for these PDEs. We will present an algorithm, that has been proposed recently, to compute entropy measure valued solutions. The algorithm has been proved to converge if the underlying discretization possesses a discrete entropy inequality and a suitable control on the oscillations of the approximate solution. We describe a set of arbitrary high-order finite volume schemes that satisfy these conditions for ensuring convergence. A large number of numerical examples for the compressible Euler equations are presented to illustrate the robustness of the proposed algorithm.

7.2 CONTRIBUTED TALKS

Numerical simulations of a fluid-particle coupling

N. Aguillon (Université Paris Sud, France)

We present numerical simulations of a model of coupling between a inviscid compressible fluid and a pointwise particle. The particle is seen as a moving interface, through which interface conditions are prescribed. Key points are to impose those conditions at the numerical level, and to deal with the coupling between an ordinary and a partial differential equations.

Gradient schemes for an obstacle problem

Y. Alnashri, J. Droniou (Monash University, Australia)

The aim of this work is to adapt the gradient schemes, discretizations of weak variational formulations using independent approximations of functions and gradients, to obstacle problems modeled by linear and nonlinear elliptic variational inequalities. It is highlighted in this paper that four properties which are coercivity, consistency, limit conformity and compactness are adequate to ensure the convergence of this scheme. Under some suitable assumptions, the error estimate for linear equations is also investigated.

Almost parallel flows in porous media

A. Armiti-Juber, Ch. Rohde (Universität Stuttgart, Germany)

This paper considers a reduced two-phase model for mostly unidirectional porous media flows. It is a nonlinear conservation law, in which velocity depends nonlocally on the unknown saturation. We aim to construct and analyze a finite-volume scheme for the model. For the analysis, the main difficulty is the reduced regularity in the transverse velocity component. The upwind finite-volume scheme is used to prove the existence of weak solutions of a regularized Cauchy problem in the framework of functions of bounded variations. Then, we consider the limit of vanishing regularization parameter. Numerical examples that analyze the efficiency of the approach are also presented.

An ALE formulation for explicit Runge–Kutta residual distribution

L. Arpaia, M. Ricchiuto (INRIA Bordeaux Sud Ouest, France)
R. Abgrall (Universität Zürich, Switzerland)

We consider the solution of hyperbolic conservation laws on moving meshes by means of an Arbitrary Lagrangian Eulerian (ALE) formulation of the Runge-Kutta RD schemes of Ricchiuto and Abgrall (J. Comput. Phys. 229, 2010). Up to the authors knowledge, the problem of recasting RD schemes into ALE framework has been solved with first order explicit schemes and with second order implicit schemes. Our resulting scheme is explicit and second order accurate when computing discontinuous solutions.

Asymptotic-preserving methods for an anisotropic model of electrical potential in a tokamak

Th. Auphan, Ph. Angot, O. Guès (CMI, France)

A 2D nonlinear model for the electrical potential in the edge plasma in a tokamak generates a stiff problem due to the low resistivity in the direction parallel to the magnetic field lines. An asymptotic-preserving method based on a micro-macro decomposition is studied in order to have a well-posed problem, even when the parallel resistivity goes to 0. Numerical tests with a finite difference scheme show a bounded condition number for the linearized discrete problem solved at each time step, which confirms the theoretical analysis on the continuous problem.

Simulation of diluted flow regimes in presence of unsteady boundaries

F. Bernard, A. Iollo (IMB, France)
G. Puppo (Universitá dell'Insubria, Italy)

The main feature of diluted flows is the presence of both continuum and kinetic regimes in the same field. The ES-BGK model is a kinetic model that preserves the asymptotic properties towards compressible Euler equations in the hydrodynamic regime, yet modeling momentum and kinetic energy diffusion for low Knudsen numbers. Here, this model is discretized by a finite-volume scheme on Cartesian meshes. The scheme is second order up to the possibly moving boundaries. To ensure a smooth transition between the hydrodynamic and the kinetic regime up to the walls, appropriate boundary conditions are devised. As an application, we present the simulation of an unsteady nozzle plume in a very low pressure environment.

On the use of the HLL-Scheme for the simulation of the multi-species Euler equations

Ph. Berndt (FU Berlin, Germany)

The HLL approximate Riemann solver is a reliable, fast and easy to implement tool for the under-resolved computation of inviscid flows. When applied to multi-species flows, it generates pressure oscillations at material interfaces. This is a well-known behavior of conservative solvers and has been addressed as a problem by several authors before. We show that for this particular solver, the generation of pressure oscillations can be desired and is consistent with the underlying physics.

Monotone combined finite volume-finite element scheme for a bone healing model

M. Bessemoulin-Chatard (LMJL - CNRS, France)
M. Saad (Ecole Centrale de Nantes, France)

We define a combined edge FV-FE scheme for a bone healing model. This choice of discretization allows to take into account anisotropic diffusions and does not impose any restrictions on the mesh. Moreover, followingq, we propose a nonlinear correction to obtain a monotone scheme. We present some numerical experiments which show its good behavior.

A new finite volume scheme for a linear Schroedinger evolution equation

A. Bradji (University of Badji Mokhtar-Annaba, Algeria)

We consider the linear Schrödinger evolution equation with a time dependent potential in several space dimension. We provide a new im plicit time finite volume scheme, using the general nonconforming meshes of [1] as discretization in space. We prove that the convergence order is $h_{\mathcal{D}}+k$, where $h_{\mathcal{D}}$ (resp. k) is the mesh size of the spatial (resp. time) discretization, in discrete norms $\mathbb{L}^\infty\left(0,T;H_0^1(\Omega)\right)$ and $\mathcal{W}^{1,\infty}\left(0,T;L^2(\Omega)\right)$. These error estimates are useful because they allow to obtain approximations to the exact solution and its first derivatives of order $h_{\mathcal{D}}+k$.

Reference:

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Vertex approximate gradient scheme for hybrid dimensional two-phase Darcy flows in fractured porous media

K. Brenner, M. Groza, R. Masson (LJAD, France)
C. Guichard (Sorbonne Universités, France)

The Vertex Approximate Gradient (VAG) discretization of a two-phase Darcy flow in discrete fracture networks (DFN) taking into account the mass exchange between the matrix and the fracture is presented. We consider the asymptotic model for which the fractures are represented as interfaces of codimension one immersed in the matrix domain with continuous pressures at the matrix fracture interface. Compared with Control Volume Finite Element (CVFE) approaches, the VAG scheme has the advantage to avoid the mixing of the fracture and matrix rocktypes at the interfaces between the matrix and the fractures, while keeping the low cost of a nodal discretization on unstructured meshes. The convergence of the scheme is proved under the assumption that the relative permeabilities are bounded from below by a strictly positive constant but cover the case of discontinuous capillary pressures. The efficiency of our approach compared with CVFE discretizations is shown on a 3D fracture network with very low matrix permeability.

Entropy-diminishing CVFE scheme for solving anisotropic degenerate diffusion equations

C. Cancès, C. Guichard (Sorbonne Universités, France)

We consider a Control Volume Finite Elements (CVFE) scheme for solving possibly degenerated parabolic equations. This scheme does not require the introduction of the so-called Kirchhoff transform in its definition. The discrete solution obtained via the scheme remains in the physical range whatever the anisotropy of the problem, while the natural entropy of the problem decreases with time. Moreover, the discrete solution converges towards the weak solution of the continuous problem. Numerical results are provided and discussed.

A finite volume scheme with the discrete maximum principle for diffusion equations on polyhedral meshes

A. Chernyshenko (Russian Academy of Sciences)
Y. Vassilevski (Moscow Institute of Physics and Technology)

We propose a cell-centered finite volume scheme with the compact stencil formed mostly by the closest neighboring cells. The discrete solution satisfies the discrete maximum principle and approximates the exact solution with second-order accuracy. The coefficients in the FV stencil depend on the solution; therefore, the FV scheme is nonlinear. The scheme is applied to a diffusion equation discretized on a general polyhedral mesh.

Convergence of a finite volume scheme for a corrosion model

P.-L. Colin, C. Chainais-Hillairet, I. Lacroix-Violet (Université Lille 1, France)

We consider a drift-diffusion system describing the corrosion of an iron based alloy in nuclear waste repository. In particular, we are interested in the convergence of a numerical scheme consisting in an implicit Euler scheme in time and a Scharfetter-Gummel finite volume scheme in space.

Asymptotic-preserving scheme based on a finite volume/particle-in-cell coupling for Boltzmann-BGK-like equations in the diffusion scaling

A. Crestetto (Université de Nantes, France)
N. Crouseilles (INRIA, France), M. Lemou (CNRS, France)

This work is devoted to the numerical simulation of the collisional Vlasov equation in the diffusion limit using particles. To that purpose, we extend the Finite Volumes/Particles hybrid scheme developed in [1], based on a micro-macro decomposition technique introduced in [2] or [3]. Whereas a uniform grid was used to approximate both the micro and the macro part of the full distribution function in [3], we use here a particle approximation for the kinetic (micro) part, the fluid (macro) part being always discretized by standard finite volume schemes. There are many advantages in doing so:

(i) the so-obtained scheme presents a much less level of noise compared to the standard particle method;

(ii) the computational cost of the micro-macro model is reduced in the diffusion limit since a small number of particles is needed for the micro part;

(iii) the scheme is asymptotic preserving in the sense that it is consistent with the kinetic equation in the rarefied regime and it degenerates into a uniformly (with respect to the Knudsen number) consis tent (and deterministic) approximation of the limiting equation in the diffusion regime.

Refereces:

[1] Crestetto, A., Crouseilles, N. and Lemou, M.: Kinetic/fluid micro-macro numerical schemes for Vlasov-Poisson-BGK equation using particles, *Kinetic and Related Models,* **5**, pp. 787–816, 2012.

[2] Bennoune, M., Lemou, M. and Mieussens, L.: Uniformly stable numerical schemes for the Boltzmann equation preserving the compressible Navier-Stokes asymptotics, *Journal of Computational Physics,* **227**, pp, 3781–3803, 2008.

[3] Lemou, M. and Mieussens, L.: A new asymptotic preserving scheme based on micro-macro formulation for linear kinetic equations in the diffusion limit, *SIAM Journal on Scientific Computing,* **31**, pp. 334–368, 2008.

An asymptotic preserving scheme for the barotropic Baer-Nunziato model

S. Dallet (EDF R&D, France)
R. Abgrall (Universität Zürich, Switzerland)

We introduce in this paper a new scheme for obtaining approximations of solutions of the barotropic Baer–Nunziato (BN) model. This scheme is expected to provide relevant approximations when relaxation time scales embedded in pressure and velocity relaxation terms vanish. A brief recall of the BN model and the asymptotic model is first given. The scheme and its main properties are described and some numerical results are provided confirming that it behaves reasonably well.

Uniform-in-time convergence of numerical schemes for Richards and Stefans models

L. Droniou (Monash University Australia)
R. Eymard (CNRS, France), C. Guichard (Sorbonne Universités, France)

We prove that all Gradient Schemes – which include Finite Element, Mixed Finite Element, Finite Volume methods – converge uniformly in time when applied to a family of nonlinear parabolic equations which contains Richards and Stefans models. We also provide numerical results to confirm our theoretical analysis.

Comparison of two couplings of the finite volume method and the boundary element method

Ch. Erath (University of Vienna, Austria)

In many fluid dynamics problems the boundary conditions may be unknown, or the domain may be unbounded. Also mass conservation and stability with respect to dominating convection is substantial. Therefore, we test two coupling methods to address these issues on the prototype of a flow and transport problem. More precisely, we couple the vertex-centered and the cell-centered finite volume method with the boundary element method, FVM-BEM and CFVM-BEM, respectively. Also robust refinement indicators are considered which allow us to steer an adaptive mesh-refinement algorithm to treat efficiently problems with singularities or boundary/internal layers-shown on two examples.

Numerical solution of fluid-structure interaction by the space-time discontinuous Galerkin method

M. Feistauer, M. Hadrava, A. Kosík (Charles University Prague, Czech Republic)
J. Horáček (The Academy of Sciences, Czech Republic)

This paper is devoted to the numerical solution of the interaction of compressible viscous flow with elastic structures. The flow in a time-dependent domain is described by the compressible Navier-Stokes equations written in the ALE formulation and the deformation of elastic structures is described by the dynamic linear elasticity system. For each individual problem we employ the discretization by the space-time discontinuous Galerkin finite element method (ST-DGM). The flow and elasticity problems are coupled via transmission conditions. The developed method is tested by numerical experiments.

Gradient schemes for Stokes problem

P. Feron, R. Eymard (LAMA, France)

We provide a framework which encompasses a large family of conforming and nonconforming numerical schemes, for the approximation of the steady state incompressible Stokes equations with homogeneous Dirichletś boundary conditions. Three examples (Taylor–Hood, extended MAC and Crouzeix–Raviart schemes) are shown to enter into this framework. The convergence of the scheme is proved by compactness arguments, thanks to estimates on the discrete solution that allow to prove the weak convergence to the unique continuous solution of the problem. Then strong convergence results are obtained thanks to the limit problem. An error estimate result is provided, applying on solutions with low regularity.

Modified finite volume nodal scheme for Euler equations with gravity and friction

E. Franck (IPP MPG Garching, Germany)

In this work we present a new finite volume scheme valid on unstructured meshes for the Euler equation with gravity and friction indeed the classical Godunov type schemes are not adapted to treat the hyperbolic systems with source terms. The new method is based on a finite volume nodal scheme modified to capture correctly the behavior induced by the source terms.

Interpolation-based second-order monotone finite volume scheme for diffusion equations on general meshes

G. Gao, Ji-Ming Wu (Beijing, China)

We propose two interpolation-based monotone schemes for the anisotropic diffusion problems on unstructured polygonal meshes through the linearity-preserving approach. The new schemes are characterized by their nonlinear two-point flux approximation, which is different from the existing ones and has no constraint on the associated interpolation algorithm for auxiliary unknowns. Thanks to the new nonlinear two-point flux formulation, it is no longer required that the interpolation algorithm should be a positivity-preserving one. The first scheme employs vertex unknowns as the auxiliary ones, and a second-order but not positivity-preserving interpolation algorithm is utilized. The second scheme uses the so-called harmonic averaging points located on cell edges to define the auxiliary unknowns, and a second-order positivity-preserving interpolation method is employed. Both schemes have nearly the same convergence rates as compared with their related second-order linear schemes. Numerical results demonstrate that the new schemes are monotone, and have the second-order accuracy for the solution and first-order for its gradient on severely distorted meshes.

On a posteriori error analysis of DG schemes approximating hyperbolic conservation laws

J. Giesselmann (Universität Stuttgart, Germany)
T. Pryer (University of Reading, UK)

We are concerned with a posteriori error analysis of discontinuous Galerkin (dG) schemes approximating hyperbolic conservation laws. In the scalar case the aposteriori analysis is based on the L^1 contraction property and the doubling of variables technique. In the system case the appropriate stability framework is in L^2, based on relative entropies. It is only applicable if one of the solutions, which are compared to each other, is Lipschitz. For dG schemes approximating hyperbolic conservation laws neither the entropy solution nor the numerical solution need to be Lipschitz. We explain how this obstacle can be overcome using a reconstruction approach which leads to an aposteriori error estimate.

Efficient parallel simulation of atherosclerotic plaque formation using higher order discontinuous Galerkin schemes

St. Girke, M. Ohlberger (Universität Münster, Germany)
R. Kloefkorn (National Center for Atmospheric Research, USA)

The compact Discontinuous Galerkin 2 (CDG2) method was successfully tested for elliptic problems, scalar convection-diffusion equations and compressible Navier-Stokes equations. In this paper we use the newly developed DG method to solve a mathematical model for early stages of atherosclerotic plaque formation. Atherosclerotic plaque is mainly formed by accumulation of lipid-laden cells in the arterial walls which leads to a heart attack in case the artery is occluded or a thrombus is built through a rupture of the plaque. After describing a mathematical model and the discretization scheme, we present some benchmark tests comparing the CDG2 method to other commonly used DG methods. Furthermore, we take parallelization and higher order discretization schemes into account.

Gradient discretization of hybrid dimensional Darcy flows in fractured porous media

C. Guichard, K. Brenner, M. Groza, G. Lebeau, R. Masson (LJLL/UMPMC, France)

This article deals with the discretization of hybrid dimensional model of Darcy flow in fractured porous media. These models couple the flow in the fractures represented as the surfaces of codimension one with the flow in the surrounding matrix. The convergence analysis is carried out in the framework of Gradient schemes which accounts for a large family of conforming and nonconforming discretizations. The Vertex Approximate Gradient (VAG) scheme and the Hybrid Finite Volume (HFV) scheme are applied to such models and are shown to verify the Gradient scheme framework. Our theoretical results are confirmed by a few numerical experiments performed both on tetrahedral and hexahedral meshes in heterogeneous isotropic and anisotropic media.

An explicit staggered finite volume scheme for the shallow water equations

P. H. Gunawan (Université Paris-Est, France)
D. Doyen (LAMA & CNRS, France)

We propose an explicit finite volume scheme for the shallow water equations. The different unknowns of the system are approximated on staggered meshes. The numerical fluxes are computed with upwind and centered discretizations. We prove a number of properties of the scheme: positivity preserving, well-balanced, consistent with the global entropy inequality. We compare it with collocated schemes, using approximate Riemann solvers, on various problems.

Simulation of diluted flow regimes in presence of unsteady boundaries

A. Iollo, F. Bernard (INRIA, France)
G. Puppo (Universitá dell'Insubria, Italy)

The main feature of diluted flows is the presence of both continuum and kinetic regimes in the same field. The ES-BGK model is a kinetic model that preserves the asymptotic properties towards compressible Euler equations in the hydrodynamic regime, yet modeling momentum and kinetic energy diffusion for low Knudsen numbers. Here, this model is discretized by a finite-volume scheme on Cartesian meshes. The scheme is second order up to the possibly moving boundaries. To ensure a smooth transition between the hydrodynamic and the kinetic regime up to the walls, appropriate boundary conditions are devised. As an application, we present the simulation of an unsteady nozzle plume in a very low pressure environment.

Stochastic modeling for heterogeneous two-phase flow

M. Köppel, I. Kröker, Ch. Rohde (Universität Stuttgart, Germany)

The simulation of multiphase flow problems in porous media often requires techniques for uncertainty quantification to represent parameter values that are not known exactly. The use of the stochastic Galerkin approach becomes very complex in view of the highly nonlinear flow equations. On the other hand collocation-like methods suffer from low convergence rates. To overcome these difficulties we present a hybrid stochastic Galerkin finite volume method (HSG-FV) that is in particular well-suited for parallel computations. The new approach is applied to specific two-phase flow problems including the example of a porous medium with a spatially random change in mobility. We emphasize in particular the issue of parallel scalability of the overall method.

FV stabilizations of FE discretizations of advection-diffusion problems

P. Knabner, F. Brunner, F. Frank (Universität Erlangen-Nürnberg, Germany)

We apply a novel upwind stabilization of a mixed hybrid finite element method of lowest order to advection–diffusion problems with dominant advection and compare it with a finite element scheme stabilized by finite volume upwinding. Both schemes are locally mass conservative and employ an upwind-weighting formula in the discretization of the advective term. Numerical experiments indicate that the upwind-mixed method is competitive with the finite volume method. It prevents the appearance of spurious oscillations and produces nonnegative solutions for strongly advection-dominated problems, while the amount of artificial diffusion is lower than that of the finite volume method. This makes the method attractive for applications in which too much numerical diffusion is critical and may lead to false predictions; e.,g., if highly nonlinear reactive processes take place only in thin interaction regions.

A DDFV scheme for incompressible Navier–Stokes equations with variable density

St. Krell, Th. Goudon (LJAD, France)

We consider the application of “Discrete Duality Finite Volume” methods for the simulation of incompressible heterogeneous viscous flows. We pay attention to the numerical coupling between the mass conservation and the momentum balance equations, together with the divergence free constraint.

Gradient evaluation on a quadtree based finite volume grid

Z. Krivá, A. Handlovičová, K. Mikula (Slovak University of Technology, Bratislava, Slovakia)

Many problems described by nonlinear PDEs need good approximations of gradients on finite volumes. Using finite volume methods, this can be difficult task if discretization of a computational domain does not fulfill the classical orthogonality property. Such a situation can occur, e.g., during coarsening in image processing using quadtree grids. We present a construction of an adjusted quadtree grid for which the connection of representative points of two adjacent finite volumes is perpendicular to their common boundary. On the other hand, for such an adjusted grid, the intersection of representative points connection with a finite volume boundary is not a middle point of their common edge. In this paper we present a new method of gradient evaluation for such a situation.

A new discretization method for the convective terms in the incompressible Navier-Stokes equations

N. Kumar, J.H.M. ten Thije Boonkkamp, B. Koren (Eindhoven University of Technology, The Netherlands)

In this contribution we present the use of local one-dimensional boundary value problems (BVPs) to compute the interface velocities in the convective terms of the incompressible Navier-Stokes equations. This technique provides us with a better estimate for the interface velocities than linear interpolants.

A well-balanced scheme for a transport equation with varying velocity arising in relativistic transfer equation

Th. Leroy, B. Després (LJLL , France)
Ch. Buet (CEA, France)

We are interest in the study of numerical schemes for the homogeneous in space asymptotic limit in the non equilibrium regime of the relativistic transfer equation. This limit leads to a frequency drift term modeling the Doppler effects for photons, and our aim is to design costless well balanced schemes. One difficulty is that wave speed may vanish, which implies that Gosse Toscani type schemes may become inconsistant in this limit. This is indeed observed numerically.

Estimating the geometric error of finite volume schemes for conservation laws on surfaces for generic numerical flux functions

Th. Müller (Universität Freiburg, Germany)
J. Giesselmann (Universität Stuttgart, Germany)

This contribution is concerned with finite volume schemes approximating scalar hyperbolic conservation laws on evolving hypersurfaces of $\mathbb{R}^{\nvDash}$. Theoretical schemes assuming knowledge of all geometric quantities are compared to (practical) schemes defined on moving polyhedra approximating the surface. For the former schemes error estimates have already been proven, but the implementation of such schemes is not feasible for complex geometries. The latter schemes, in contrast, only require (easily) computable geometric quantities and are thus more useful for practical computations. In [Giesselmann, J., Müller, T.: Geometric error of finite volume schemes for conservation laws on evolving surfaces. Numer. Math. (2014)] an estimate for the difference between solutions of both classes of schemes is proven. This estimate relies on an estimate for the geometric error of the numerical fluxes, which will be investigated in more detail in this contribution.

A simple finite volume approach to compute flows in variable cross-section ducts

X. Martin, B. Audebert, J.-M. Hérard, O. Touazi (EDF R&D, France)

In order to derive a simple one-dimensional approach that could handle fluid flows in smooth ducts as well as in ducts of discontinuous cross-section, we propose herein a Finite Volume approach that relies on an integral formulation of the multidimensional flow model. While focusing on Euler equations, we compare twodimensional results with approximations obtained using the present approach, and also with the classical formulation for variable cross-sections using a well-balanced scheme. Numerical simulations confirm the ability of this integral method to provide approximations that compare well with 2D results. This method also enables to deal with all -even including vanishing- cross-section ducts. This approach may also be applied when considering other single-phase or multi-phase fluid flow models.

A mixed explicit implicit time stepping scheme for Cartesian embedded boundary meshes

S. May, M. Berger (ETH Zürich, Switzerland)

We present a mixed explicit implicit time stepping scheme for solving the linear advection equation on a Cartesian embedded boundary mesh. The scheme represents a new approach for overcoming the small cell problem – that standard finite volume schemes are not stable on the arbitrarily small cut cells. It uses implicit time stepping on cut cells for stability. On standard Cartesian cells, explicit time stepping is employed. This keeps the cost small and makes it possible to extend existing schemes from Cartesian meshes to Cartesian embedded boundary meshes. The coupling is done by *flux bounding,* for which we can prove a TVD result. We present numerical results in one and two dimensions showing second-order convergence in the L^1 norm and between first- and second-order convergence in the L^∞ norm.

Consistency analysis of a 1D finite volume scheme for barotropic Euler models

S. Minjeaud, F. Berthelin, Th. Goudon (LJAD, France)

This work is concerned with the consistency study of a 1D (staggered kinetic) finite volume scheme for barotropic Euler models. We prove a Lax-Wendroff-like statement: the limit of a converging (and uniformly bounded) sequence of stepwise constant functions defined from the scheme is a weak entropic-solution of the system of conservation laws.

A combined finite volume discontinuous Galerkin approach for the sharp-interface tracking in multi-phase flow

C.-D. Munz, St. Fechter (Universität Stuttgart, Germany)

In this paper, a numerical method for the simulation of compressible twophase flows is presented. The multi-scale approach consists of several components that allow to sharply resolve the discontinuous nature of multi-phase flow: A discontinuous Galerkin solver for the macroscopic scales of the flow, a micro-scale Riemann solver at the interface that supplies the necessary interfacial jump conditions, a ghost-fluid based coupling of the interfacial conditions to the flow, and a level-set interface tracking formalism. To be able to locally guarantee a sharp and stable resolution at the interface, a finite volume technique on an adaptive subcell refinement is applied. The capabilities of the method are demonstrated for a threedimensional shock-droplet interaction problem.

Nonlinear monotone FV scheme for radionuclide geomigration and multiphase flows models

K. Nikitin, I. Kapyrin, K- Terekhov, Y. Vassilevski (Institute of Nuclear Safety, Russia)

We present application of the nonlinear monotone finite volume method to radionuclide geomigration and multiphase flows models. The scheme is applicable for full anisotropic discontinuous permeability or diffusion tensors and arbitrary conformal polyhedral cells. We compare the new nonlinear scheme with conventional linear two-point and multi-point flux approximation O-scheme. The new nonlinear scheme has a number of important advantages over the traditional linear discretizations. We also consider hybrid approach which combines linear and nonlinear two-point flux approximation schemes.

Positivity preserving implicit and partially implicit time integration methods in the context of the DG scheme applied to shallow water flows

S. Ortleb (Universität Kassel, Germany)

This contribution is concerned with the development of unconditionally positive implicit time integration schemes in the context of shallow water flows discretized by the DG scheme. For explicit time integration – which is mostly applied in combination with wetting and drying shallow water flows – both linear stability and positivity preservation require very small time steps. Also for implicit Runge-Kutta schemes, positivity preservation generally leads to additional time step restrictions. In this work, we discuss two possible extensions to implicit time integration schemes that guarantee non-negativity of the water height for any time step size while still preserving the conservativity of the space discretization.

3D Lagrangian segmentation with simultaneous mesh adjustment

M. Remešiková, K. Mikula (Slovak University of Technology, Slovakia)

We present a method for 3D image segmentation based on the Lagrangian approach. The segmentation model is a 3D analogue of the geodesic active contour model and it contains an additional tangential movement term that allows us to control the quality of the mesh during the evolution process. The model is discretized by the finite volume approach. Segmentation of zebrafish cell images is shown to illustrate the performance of the method.

Coupling free flow and porous medium flow systems using sharp interface and transition region concepts

I. Rybak (Universität Stuttgart, Germany)

Two different coupling approaches for isothermal single-phase free flow and isothermal single-fluid-phase porous medium systems are considered: sharp interface and transition region approach. The sharp interface concept implies the Beavers–Joseph–Saffman velocity jump condition together with restrictions that arise due to mass conservation and balance of normal forces across the fluid-porous interface. The transition region model is derived by means of the thermodynamically constrained averaging theory (TCAT). The equations are averaged over the thickness of the transition zone in the direction normal to the free flow and porous medium domains being joined. Coupling conditions are the mass conservation, the momentum balance and a generalization of the Beavers–Joseph condition. Two model formulations are compared and numerical simulation results are presented. For discretization of the coupled problem the finite volume method on staggered grids is used.

Comparison of realizable schemes for the Eulerian simulation of disperse phase flows

M. Sabat, A. Larat, M. Massot (CNRS/UPR, France)
A. Vié (Standford University, CA)

In the framework of fully Eulerian simulation of disperse phase flows, the use of a monokinetic closure for the kinetic based moment method is of high importance since it accurately reproduces the physics of low inertia particles with a minimum number of moments. The free transport part of this model leads to a pressureless gas dynamics system which is weakly hyperbolic and can generate δ-shocks. These singularities are difficult to handle numerically, especially without globally degenerating the order or disrespecting the realizability constraints. A comparison between three second order schemes is conducted in the present work. These schemes are: a realizable MUSCL/HLL finite volume scheme, a finite volume kinetic scheme, and a convex state preserving Runge–Kutta discontinuous Galerkin scheme. Even though numerical computations have already been led in 2D and 3D with this model and numerical methods, the present contribution focuses on 1D results for a full understanding of the trade off between robustness and accuracy and of the impact of the limitation procedures on the numerical dissipation. Advantages and drawbacks of each of these schemes are eventually discussed.

A staggered scheme with non-conforming refinement for the Navier–Stokes equations

K. Saleh, F. Babik, J.-C. Latché, B. Piar (IRSN, France)

We propose a numerical scheme for the incompressible Navier-Stokes equations. The pressure is approximated at the cell centers while the vector valued velocity degrees of freedom are localized at the faces of the cells. The scheme is able to cope with unstructured non-conforming meshes, involving hanging nodes. The discrete convection operator, of finite volume form, is built with the purpose to obtain a stability property, namely, a discrete equivalent to the kinetic energy identity. The diffusion term is approximated by extending the usual Rannacher-Turek finite element to non-conforming meshes. The scheme is first order in space for energy norms, as shown by the numerical experiments.

Well-balanced inundation modeling for shallow-water flows with discontiuous Galerkin schemes

St. Vater, J. Behrens (Universität Hamburg, Germany)

Modeling coastal inundation for tsunami and storm surge hazard mitigation is an important application of geoscientific numerical modeling. While the complex topography demands for robust and locally accurate schemes, computational parallel efficiency and discrete conservation properties of the scheme are required. In order to meet these requirements, Runge–Kutta discontinuous Galerkin numerical methods are attractive. However, maintaining conservation and well-balancedness of these schemes with wetting/drying boundary conditions poses a challenge. We address this issue by a local nondestructive modification of the flux computation at boundary cells, which maintains accuracy, conservation and well-balancedness. The development can be viewed as a specialized flux limiter, which proves its usefulness with three different test cases for inundation simulation.

A conservative coupling of level-set, volume-of-fluid and other conserved quantities

M. Waidmann, St. Gerber, R. Klein (FU Berlin, Germany)
M. Oevermann (Chalmers University of Technology, Sweden)

A conservative level-set volume-of-fluid synchronization strategy including coupling to other conserved quantities such as mass or momentum is presented. The scheme avoids mass loss/gain of fluidic structures in zero Mach number two-phase flow while keeping the interface between the two fluid phases sharp. Local level-set correction and a consistent discretization error control using information from the energy equation based divergence constraint allow for application of the presented method to both constant and variable density zero Mach number two-phase flow with or without interfacial mass transport.

Comparison of cell-centered and staggered pressure-correction schemes for all-Mach flows

C. Zaza, N. Therme (CEA Cadarache, France)

Defining a robust scheme for solving the compressible Euler equations at Mach regimes is a challenging issue. We consider here an original pressure-correction scheme which solves the internal energy using a specific discrete source term, ensuring the positivity of the internal energy and the global consistency of the scheme. The scheme has already proved its effectiveness on several Riemann problems with both staggered and cell-centered discretizations. We test here these two discretizations against the incompressible limit of the Euler equations and try to analyze the differences resulting from it.

A well-balanced scheme for the Euler equation with a gravitational potential

M. Zenk, , Ch. Klingenberg (Universität Würzburg, Germany)
Ch. Berthon (UMR. France), V. Desveaux (CEA Saclay, France)

The aim of this work is to derive a well-balanced numerical scheme to approximate the solutions of the Euler equations with a gravitational potential. This system admits an infinity of steady state solutions which are not all known in an explicit way. Among all these solutions, the hydrostatic atmosphere has a special physical interest. We develop an approximate Riemann solver using the formalism of Harten, Lax and van Leer, which takes into account the source term. The resulting numerical scheme is proven to be robust, to preserve exactly the hydrostatic atmosphere and to preserve an approximation of all the other steady state solutions.

Numerical dissipation and dispersion of the homogeneous and complete flux schemes

J. ten Thije Boonkkamp, M.J.H. Anthonissen (Eindhoven University of Technology, The Netherlands)

We analyze numerical dissipation and dispersion of the homogeneous flux (HF) and complete flux (CF) schemes, finite volume methods introduced in [1]. To that purpose we derive the modified equation of both schemes. We show that the HF scheme suffers from numerical diffusion for dominant advection, which is effectively removed in the CF scheme. The latter scheme, however, is prone to numerical dispersion. We validate both schemes for a model problem.

Reference:

[1] ten Thije Boonkkamp J. and Anthonissen, M.: The finite volume-complete flux scheme for advection-diffusion-reaction equations *Journal of Scientific Computing,* **46(1)**, 47–70, 2011.

Towards a stochastic closure approach for large eddy simulation

Th. von Larcher, R. Klein, M. Waidmann (FU Berlin, Germany)
I. Horenko, D. Igdalov, P. Metzner (Universitá dell'Swizzerá, Italy), A. Beck, C.-D. Munz (Universität Stuttgart, Germany), G. Gassner (Universität zu Köln, Germany)

We present a stochastic sub grid scale modeling strategy currently under development for application in Finite Volume Large Eddy Simulation (LES) codes. Our concept is based on the integral conservation laws for mass, momentum and energy of a flow field that are universally valid for arbitrary control volumes. We model the space-time structure of the fluxes to create a discrete formulation. Advanced methods of time series analysis for the data-based construction of stochastic models with inherently non-stationary statistical properties and concepts of information theory for the model discrimination are used to construct stochastic surrogate models for the non-resolved fluctuations. Vector-valued auto-regressive models with external influences (VARX-models) form the basis for the modeling approach. The reconstruction capabilities of the modeling ansatz are tested against fully three dimensional turbulent channel flow data computed by direct numerical simulation (DNS). We present here the outcome of our reconstruction tests.

7.3 POSTER

The complete flux scheme in cylindrical coordinates

M. Anthonissen, J.H.M. ten Thije Boonkkamp (Eindhoven University of Technology, The Netherlands)

We consider the complete flux (CF) scheme, a finite volume method based on an integral representation for the fluxes, found by solving a local boundary value problem that includes the source term. It performs well (second order accuracy) for both diffusion and advection dominated problems. In this talk we focus on cylindrically symmetric conservation laws of advection-diffusion-reaction type.

A 1D stabilized finite element model for non-hydrostatic wave breaking and run-up

P. Bacigaluppi, Ph. Bonneton (INRIA, France)
M. Ricchiuto (Bordeaux University, France)

We present a stabilized finite element model for wave propagation, breaking and run-up. Propagation is modeled by a form of the enhanced Boussinesq equations, while energy transformation in breaking regions is captured by reverting to the shallow water equations and allowing waves to locally converge into discontinuities. To discretize the system we propose a non-linear variant of the stabilized finite element method of (Ricchiuto and Filippini, J. Comput. Phys. 2014). To guarantee monotone shock capturing, a non-linear mass-lumping procedure is proposed which locally reverts the third order finite element scheme to the first order upwind scheme. We present different definitions of the breaking criterion, including a local implementation of the convective criterion of (Bjorkavaag and Kalisch, Phys. Letters A 2011), and discuss in some detail the implementation of the shock capturing technique. The robustness of the scheme and the behavior of different breaking criteria is investigated on several cases with available experimental data.

Semi-implicit second order accurate finite volume method for advection-diffusion level set equation

M. Balažovjech, R. Frolkovič, K. Mikula (Slovak University of Technology, Slovakia)

We present a second order accurate finite volume method for level set equation describing the motion in normal direction with the speed depending on external force and curvature. A convenient combination of a Crank-Nicolson type of the time discretization for diffusion term [1] and an Inflow Implicit and Outflow Explicit scheme [2] for advection term is used. Numerical experiments for an example with the exact solution derived in this paper and for examples motivated by modeling of fire propagation in forests are presented.

References:

[1] Balažovjech, M. and Mikula, K.: A higher order scheme for a tangentially stabilized plane curve shortening flow with a driving force, *SIAM J. Sci. Comp.,* **33**, pp. 2277–2294, 2011.

[2] Mikula, K. and Ohlberger, M.: A new level set method for motion in normal direction based on a semi-implicit forward-backward diffusion approach, *SIAM J. Sci. Comp.*, **32**(3), pp. 1527–1544, 2010.

Adaptive time discretization and linearization based on a posteriori estimates for the Richards equation

V. Baron, P. Sochala (Université de Nantes/BRGM, France)
Y. Coudière (IMB, France)

We derive some a posteriori error estimates for the Richards equation, based on the dual norm of the residual. This equation is nonlinear in space and in time, thus its resolution requires fixed-point iterations within each time step. We propose a strategy to decrease the computational cost relying on a splitting of the error terms in three parts: Linearization, time discretization, and space discretization. In practice, we stop the fixed-point iterations after the linearization error becomes negligible, and choose the time step in order to balance the time and space errors.

A. Bradji (University of Badji Mokhtar-Annaba, Algeria)

Poster I: A note on a new second order approximation based on a low–order finite volume scheme for the wave equation in one space dimension

This note is an extension of our previous work [1] which dealt with a first order finite volume scheme for the wave equation. We construct a new second order approximation for the solution of the wave equation in one space dimension. This new high-order approximation can be computed using the same simple scheme used in [1] and its formulation includes an approximation which together with their first and second time derivatives converge towards their corresponding time derivat ives of the second spatial derivative of the exact solution. The analysis provided in this note is based on the use of a new a priori estimate.

Reference:

[1] Bradji, A.: A theoretical analysis of a new finite volume scheme for second order hyperbolic equations on general nonconforming multidimensional spatial meshes, *Numer. Methods Partial Differ. Eq.,* **29**(1), 1–39, 2013.

Poster II: Note on the convergence of a finite volume scheme using a general nonconforming mesh for an oblique derivative boundary value problem

This note is an extension of our work [1], which dealt with the convergence of a finite volume approximation using the admissible mesh of [2], for oblique derivative boundary value problems. In this note, we provide a finite volume scheme for the Laplace equation with an oblique boundary condition, using the general nonconforming meshes and the discrete gradient introduced recently in [3]. A convergence order for an approximation for the gradient of the exact solution is proved.

References:

[1] Bradji, A. and Gallouët, T.: Error estimate for finite volume approximate solutions of some oblique derivative boundary problems, *International Journal on Finite Volumes,* **3**(2), 35 pages (electronic), 2006.

[2] Eymard, R., Gallouët, T. and Herbin, R.: Finite Volume Methods, *Handbook of Numerical Analysis*, P. G. Ciarlet and J. L. Lions (eds.) VII, pp. 723–1020, 2000.

[3] Eymard, R., Gallouët T. and Herbin, R.: Discretization of heterogeneous and anisotropic diffusion problems on general nonconforming meshes SUSHI: a scheme using stabilization and hybrid interfaces, *IMA J. Numer. Anal.,* **30**(4), pp. 1009–1043, 2010.

Conservative finite differences as an alternative to finite volume for compressible flows

J. Brouwer, J. Reiss, J. Sesterhenn (TU Berlin, Germany)

Finite Volume schemes are the natural choice when simulating flows with shocks, since conservation is essential in the physics and as such in the simulation of this phenomenon. But finite difference schemes can be conservative as well. Conservation requires in such schemes a high internal consistency of the spatial and the temporal discretization. We present a skew-symmetric finite difference scheme, which is fully conservative due to its consistency, still easy to implement and numerically efficient. A variety of different flow configurations containing shocks and turbulence are presented.

A uniformly converging scheme for fractal conservation laws

J. Droniou (Monash University, Australia)
E. Jakobsen (Norwegian University, Trondheim)

The fractal conservation law $\partial_t u + \partial_x(f(u)) + (-\Delta)^{\alpha/2}u = 0$ changes characteristics as $\alpha \to 2$ from non-local and weakly diffusive to local and strongly diffusive. In this paper we present a corrected finite difference quadrature method for $(-\Delta)^{\alpha/2}$ with $\alpha \in [0, 2]$, combined with usual finite volume methods for the hyperbolic term, that automatically adjusts to this change and is uniformly convergent with respect to $\alpha \in [\eta, 2]$ for any $\eta > 0$. We provide numerical results which illustrate this asymptotic-preserving property as well as the non-uniformity of previous finite difference or finite volume type of methods.

Numerical simulation of flow in a meridional plane of multistage turbine

J. Fürst, J. Fořt, J. Halama, J. Holman, J. Karel, V. Prokop, D. Trdlička (CTU, Czech Republic)

The paper presents a numerical method, which simulates the circumferentially averaged steady flow of a compressible fluid in a multistage turbine. The method is considered in the analytic mode with known geometry. It is intended as a fast tool to turbine designers, which provides the distribution of the flow parameters in the meridional plane, gives the information about mass flow and estimates the efficiency of turbine. The method is based on the solution of the circumferentially averaged three-dimensional Euler equations complemented by the source terms related to the turbine geometry and to the loss prediction model. The meridional plane is discretized by a structured grid. Equations are solved by a finite volume method with the AUSM type numerical flux. Examples including the transonic flow in a turbine stator and in a stage are presented.

An anisotropic diffusion finite volume algorithm using a small stencil

M. Ferrand, J. Fontaine, O. Angelini (EDF R&D, France)

This talk presents a finite volume algorithm to solve anisotropic heterogeneous diffusion equations within the open source CFD software *Code_Saturne.* This algorithm has the advantage to use a small stencil composed of face neighboring cells only, which makes it easy to parallelize. The resolution is performed through an iterative process (fixed point Picard algorithm). Second order convergence in space is numerically obtained on various analytical test-cases and mesh sequences of the FVCA6 benchmark and the results are compared to the barycentric version of the SUSHI scheme [1].

Reference:

[1] Eymard, R., Gallouët, T. and Herbin, R.: Discretization of heterogeneous and anisotropic diffusion problems on general nonconforming meshes sushi: a scheme using stabilization and hybrid interfaces, *IMA Journal of Numerical Analysis,* **30**(4), pp. 1009-âĂŞ1043, 2010.

Uniform estimate of the relative free energy by the dissipation rate for finite volume discretized reaction-diffusion systems

A. Fiebach (PTB Berlin, Germany)
A. Glitzky (WIAS Berlin, Germany)

We prove a uniform Poincaré-like estimate of the relative free energy by the dissipation rate for implicit Euler, finite volume discretized reaction-diffusion systems. This result is proven indirectly and ensures the exponential decay of the relative free energy with a unified decay rate for admissible finite volume meshes. The decay rate is illustrated by a numerical example.

Activity based finite volume methods for generalised Nernst–Planck–Poisson systems

J. Fuhrmann (WIAS Berlin, Germany)

The paper shortly introduces models which improve the Nernst–Planck–Poisson system to obtain more realistic ion concentrations near electrode surfaces in comparison to classical models. The resulting equations are reformulated using activities as basic variables describing the species amounts. This reformulation allows to introduce a straightforward generalization of the Scharfetter–Gummel scheme for drift-diffusion equations. Numerical examples demonstrate the improved physical correctness of the generalized model, the thermodynamic consistency in the sense of the decay of the free energy, and the usefulness in nanofluidic problems.

Suitable formulations of Lagrange remap finite volume schemes for manycore / GPU architectures

Th. Gasc (CEA, France)
F. de Vuyst (CMLA/UMR, France)

This talk is dedicated to Lagrange-Remap schemes (also referred to as Lagrange-Euler schemes) and their suitable formulations for manycore/GPU architectures. High performance computing efficiency requires a suitable balance between floating point operations and memory accesses, uniform compactly supported stencils, memory alignment, SIMD-based instructions and minimal dereferencing into memory. We provide various formulations, from the basis geometrical remapping to remap by flux balances and operator splitting variant approach. We present numerical experiments of two-dimensional Euler hydrodynamics on Cartesian grids up to 2048*2048 cells and provide performance results.

Some applications of a two-fluid model

J.-M. Hérard, F. Crouzet, F. Daude, , H. Olivier, Y. Liu (LATP, France)
P. Galon (CEA Saclay, France)

We present in this paper some comparisons of numerical results and experimental data in some two-phase flows involving rather high pressure ratios. A two-fluid two-phase flow model has been used herein, but we also report a few results obtained with some simpler single-fluid two-phase flow models.

Semi-implicit alternating discrete duality finite volume scheme for curvature driven level set equation

A. Handlovičová, P. Frolkovič (Slovak University of Technology, Slovakia)

Linear semi-implicit Alternating Discrete Duality Finite Volume (ADDFV) numerical scheme for the solution of regularized curvature driven level set equation is presented. The scheme requires in each time step to solve algebraic system with a half number of unknowns than necessary in standard DDFV scheme. The stability estimations are proved and comparisons for one numerical experiment are provided.

An efficient implementation of a CeVeFE DDFV scheme on cartesian grids and an application in image processing

N. Hartung, F. Hubert (LATP, France)

In this work we describe the implementation of a 3D Center-Vertex-Face/Edge Discrete Duality Finite Volume (CeVeFE DDFV) scheme using only the degrees of freedom (DOF) disposed on a Cartesian grid. These DOF are organized in a three-mesh structure proper to the CeVeFE DDFV setting. Reposing on a diamond structure, the approach presented here greatly simplifies the implementation, also in the case of grids topologically equivalent to the uniform Cartesian one. The numerical scheme is then applied to a problem in image processing, where uniform Cartesian structure of the DOF is naturally imposed by the pixel/voxel structure. A semi-implicit DDFV scheme is used for solving a nonlinear advection- diffusion equation, the subjective surfaces equation, in order to reconstruct the volume of a tumour from noisy 3D SPECT images with signal intensity on the tumour boundary. The matrix of the linear system has a band structure and the method is fast and able to successfully reconstruct the tumour volume.

On the Godunov scheme applied to the linear wave equation with void fraction

J. Jung (LJLL/UPMC, France)
D. Stéphane, P. Omnes (CEA, France)

We introduce tools to study the behavior at low Mach number of the Godunov finite volume scheme applied to the linear wave equation with void fraction. More precisely, we extend the Hodge decomposition to a weighted L^2 space and we study the properties of the modified equation associated to this Godunov scheme.

Convergence of finite volume scheme for degenerate parabolic problem with zero flux boundary condition

M. Karimou Gazibo (Université de Franche-Comte, France)

This note is devoted to the study of the finite volume methods used in the discretization of degenerate parabolic-hyperbolic equation with zero-flux boundary condition. The notion of an entropy-process solution, successfully used for the Dirichlet problem, is insufficient to obtain a uniqueness and convergence result because of a lack of regularity of solutions on the boundary. We infer the uniqueness of an entropy-process solution using the tool of the nonlinear semigroup theory by passing to the new abstract notion of integral-process solution. Then, we prove that numerical solution converges to the unique entropy solution as the mesh size tends to 0.

Numerical modelling of viscous and viscoelastic fluids flow in the channel with t-junction

R. Keslerová, K. Kozel, D. Trdlička (Czech Technical University, Czech Republic)

In this work the numerical solution of the viscous and viscoelastic fluids flow for generalized Newtonian and Oldroyd-B fluids are considered. The governing system of equations is the system of generalized Navier+-Stokes equations for incompressible laminar fluids. For the stress tensor on the right hand side of this system two different mathematical models are used. For viscous fluids flow Newtonian model is used. For Oldroyd-B fluids flow Oldroyd-B model is considered. Both tested mathematical models can be generalized for the numerical modeling of the generalized Newtonian and Oldroyd-B fluids flow. In this case the viscosity function $\mu(\dot{\gamma})$ is defined by shear-thinning generalized cross model. The finite volume method combined with the artificial compressibility method is used for the spatial discretization. For the time discretization the explicit multistage Runge-Kutta scheme is used. Computational domain is formed by the branched channel with one inlet and two outlet parts. The cross-section is square and the branch is perpendicular to the main pipe. The numerical results of generalized Newtonian and generalized Oldroyd-B fluids flow obtained by this method are presented.

Convergence of a nonlinear scheme for anisotropic diffusion equations

Ch. Le Potier (CEA Saclay, France)

We study a nonlinear correction depending on a parameter ν to eliminate oscillations appearing in the discretization of diffusion operators. For $\nu = 1$, it satisfies the LMP structure. For $\nu < 1$, with a few non restrictive assumptions on the mesh, we prove the convergence of this scheme. Using an analytical solution, we show the robustness and the accuracy of this algorithm in comparison with results obtained by linear schemes which do not satisfy the minimum principle on this test.

Optimal and pressure-independent L2 velocity error estimates for a modified Crouzeix-Raviart element with BDM reconstructions

A. Linke, Ch. Merdon (WIAS Berlin, Germany)
Ch. Brennecke (ETH Zürich, Switzerland), J. Schöberl (TU Wien, Austria)

Nearly all inf-sup stable mixed finite elements for the incompressible Stokes equations relax the divergence constraint. The price to pay is that a-priori estimates for the velocity error become pressure-dependent, while *divergence-free* mixed finite elements deliver *pressure-independent* estimates. A recently introduced new variational crime using lowest-order Raviart-Thomas velocity reconstructions delivers a much more robust modified Crouzeix-Raviart element, obeying an optimal *pressure-independent* discrete H^1 velocity estimate. Refining this approach, a more sophisticated variational crime employing the lowest-order BDM element is proposed, which also allows proving an optimal pressure-independent L^2 *velocity error.* Numerical examples confirm the numerical analysis.

Mimetic finite difference schemes with the conditional maximum principle for diffusion problems

K. Lipnikov (Los Alamos, USA)

Numerical schemes that satisfy the maximum principle play important role in multiphysics codes. They reduce significantly various numerical artifacts. We describe a novel inexpensive practical algorithm for building mimetic finite difference schemes with conditional maximum principle on polygonal and polyhedral meshes for diffusion problems.

Convergence of the MAC scheme for the steady-state incompressible Navier-Stokes equations on non-uniform grids

M. Mallem, R. Herbin (Aix-Marseille Université, France)
J.-C. Latché (IRSN Cadarache, France)

We prove in this paper the convergence of the Marker and cell (MAC) scheme for the discretization of the steady-state incompressible Navier-Stokes equations in primitive variables on non-uniform Cartesian grids, without any regularity assumption on the solution. A priori estimates on solutions to the scheme are proven; they yield the existence of discrete solutions and the compactness of sequences of solutions obtained with family of meshes the space step of which tends to zero. We then establish that the limit is a weak solution to the continuous problem.

Discrete relative entropy for the compressible Stokes problem

D Maltese, A. Novotny (University of Toulon, France)
Th. Gallöuet (Universite de Provence, France)

In this paper, we propose a discretization for the nonsteady compressible Stokes problem.. This scheme is based on Crouzeix–Raviart approximation spaces. The discretization of the momentum balance is obtained by the usual finite element technique. The discrete mass balance is obtained by a finite volume scheme, with an upwinding of the density. The time discretization will be implicit in time. We prove the existence of a discrete solution. We prove that our scheme satisfies a discrete version of the relative entropy. As a consequence, we obtain an error estimate for this system. This preliminary work will be used in order to obtain a error estimate for the compressible Navier–Stokes system and has to the author's knowledge not been studied previously.

High performance computing linear algorithms for two-phase flow in porous media

R. Masson, R. Eymard (University Nice Sophia Antipolis, France)
C. Guichard (Sorbonne Universités, France)

We focus here on the difficult problem of linear solving, when considering implicit scheme for two-phase flow simulation in porous media. Indeed, this scheme leads to ill-conditioned linear systems, due to the different behaviors of the pressure unknown (which follows a diffusion equation) and the saturation unknown (mainly adverted by the total volumic flow). This difficulty is enhanced by the parallel computing techniques, which reduce the choice of the possible preconditioners. We first present the framework of this study, and then we discuss different algorithms for linear solving. Finally, numerical results show the performances of these algorithms.

Modeling phase transition and metastable phases

H. Mathis (LMJL, France)
F. James (University Orléans, France)

We propose a model that describes phase transition including metastable phases present in the van der Waals Equation of State (EoS). We introduce a dynamical system that is able to depict the mass transfer between two phases, for which equilibrium states are both metastable and stable states, including mixtures. The dynamical system is then used as a relaxation source term in a isothermal two-phase model. We use a Finite Volume scheme (FV) that treats the convective part and the source term in a fractional step way. Numerical results illustrate the ability of the model to capture phase transition and metastable states.

An arbitrary space-time high-order finite volume scheme for gas dynamics equations in curvilinear coordinates on polar meshes

B.-J. Meltz, St. Jaouen (CEA, France)
F. Lagoutière (Université Paris-Sud, Frande)

We are interested in the study of numerical schemes for the resolution of gas dynamics equations which preserve symmetric (or axisymmetric) flows. A simple way to achieve this is to derive a numerical scheme whose mesh and coordinates system are aligned with the flow. Typically, for the simulation of cylindrical implosions of gas, the cylindrical coordinate system and a polar mesh are well-suited. But such coordinates systems introduce geometrical singularities as well as geometrical source terms. In this paper, we investigate an arbitrary high-order space-time Finite Volume (FV) scheme in cylindrical coordinates. Test-cases with and without polar symmetries are studied in order to confirm the order of the scheme as well as its robustness.

Coupling of fluid flow and solute transport using a divergence-free reconstruction of the Crouzeix-Raviart element

Ch. Merdon, J. Fuhrmann, A. Linke (WIAS Berlin, Germany)

The nonconforming Crouzeix-Raviart finite element discretization for the Navier-Stokes equations allows for a divergence-free reconstruction of the discrete velocity field in the Raviart-Thomas finite element space. Integration over the faces of the control volumes of an admissible finite volume subdivision of the normal components of this reconstructed velocity field allows the coupling to the two-point flux based exponential fitting finite volume method for mass transport. The main advantage of this scheme is that it preserves positivity and maximum principles for the concentration. In comparison to previously introduced coupling schemes based on divergence-free finite element ansatzes for the fluid flow, the new method uses a significantly smaller number of degrees of freedom. The paper introduces the coupling method, demonstrates the preservation of the qualitative properties of the discrete concentration field and, based on numerical experiments, establishes the hypothesis that the coupled scheme is convergent.

A conservative well-balanced hybrid SPH scheme for the shallow-water model

V. Michel-Dansac, Ch. Berthon (Université de Nantes, France)
M. de Leffe (HydrOcean, France)

A scheme defined by a hybridization between SPH method and finite volume method is considered. The aim of the present communication is to derive a suitable discretization of the source term to enforce the required well-balanced property. To address such an issue, we adopt a relevant reformulation of the flux function by involving the free surface instead of the water height. Such an approach gives a natural discretization of the topography source term in order to preserve the lake at rest. Moreover, we prove that the scheme is in conservative form, which is, in general, a very difficult task since we do not impose restrictive assumptions on the SPH method. Several 1D numerical experiments are performed to exhibit the properties of the scheme.

Finite volume analysis for the Cahn-Hilliard equation with dynamic boundary conditions

F Nabet (CNRS, France)

This work is devoted to the convergence analysis of a finite volume approximation of the 2D Cahn-Hilliard equation with dynamic boundary conditions. The method that we propose couples a 2D-finite volume method in a bounded smooth domain $\Omega \subset \mathbb{R}^2$ and a 1d-finite volume method on $\partial\Omega$. We prove convergence of the sequence of approximate solutions. One the main ingredient is a suitable space translation estimate that gives a limit in $L^\infty(0, T, H^1(\Omega))$ whose trace is in $L^\infty(0, T, H^1(\Omega))$.

Weak convergence of nonlinear finite volume schemes for linear hyperbolic systems

M. Ndjinga (CEA Saclay, France)

We prove the weak convergence of nonlinear finite volume schemes applied to symmetric hyperbolic systems of linear partial differential equations on $\mathbb{R}^d$. The upwinding matrix can be any nonlinear non negative matrix valued function, the initial data any possibly discontinuous function in $L^2(\mathbb{R}^d)$ and the mesh may be smoothly unstructured.

On boundary approximation for simulation of granular flow

D. Neusius, S. Schmidt (ITWM Kaiserslautern, Germany)
A. Klar (TU Kaiserslautern, Germany)

We introduce a Cartesian cut-cell method to numerically solve a system of granular equations in complicated domains. A non-Newtonian Navier–Stokes model is used, which covers both the dense and dilute regime of granular flow. In a Cartesian cut-cell method, one starts from a Cartesian grid and modifies cells that intersect the boundary. In contrast to adaptive or boundary fitting grids, the cutting process yields only local modifications. Thus, the simple Cartesian finite volume structure can be sustained on the interior. To ensure stability in the presence of arbitrarily small cut cells, a merging process will be used, which will result in a combination of the discretization equations on the algebraic level. An interpolation is used to ensure first order convergence near the boundary. We restrict the presentation of numerical examples to two dimensions, while the method derivation includes the three dimensional case.

Numerical simulation of an incompressible two-fluid model

Nguyen, T.-P.-K. Nguyen (CEA Saclay, France)
Ch. Chalons (Université Versailles, France)

We investigate some finite volume methods for the numerical simulation of a flow involving two incompressible phases in mechanical disequilibrium. The model consists of two hyperbolic equations with characteristic fields that are neither linearly degenerate nor genuinely nonlinear. We show that the system may involve sonic points, hence the importance of using entropic schemes to accurately capture the volume fraction waves. W e propose a Godunov scheme and a Roe scheme with a Harten type correction and compare them on test cases involving the transition between two phase and single phase flows.

A-posteriori error estimates for the localized reduced basis multi-scale method

M. Ohlberger, F. Schindler (Universität Münster, Germany)

We present a localized a-posteriori error estimate for the localized reduced basis multi-scale (LRBMS) method [1]. The LRBMS is a combination of numerical multi-scale methods and model reduction using reduced basis methods to efficiently reduce the computational complexity of parametric multi-scale problems with respect to the multi-scale parameter ϵ and the online parameter μ simultaneously. We formulate the LRBMS based on a generalization of the SWIPDG discretization presented in [2] on a coarse partition of the domain that allows for any suitable discretization on the fine triangulation inside each coarse grid element. The estimator is based on the idea of a conforming reconstruction of the discrete diffusive flux, that can be computed using local information only. It is offline/online decomposable and can thus be efficiently used in the context of model reduction.

References:

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Application of a two-fluid model to simulate the heating of two-phase flows

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This paper is dedicated to the simulation of two-phase flows on the basis of a two-fluid model that allows to account for the disequilibrium of velocities, pressures, temperatures and chemical potentials (mass transfer). The numerical simulations are performed using a fractional step method treating separately the convective part of the model and the source terms. The scheme dealing with the convective part of the model follows a Finite Volume approach and is based on a relaxation scheme. In the sequel, a special focus is put on the discretization of the terms that rule the mass transfer. The scheme proposed is a first order implicit scheme and can be verified using an analytical solution. Eventually, a test case of the heating of a mixture of steam and water is presented, which is representative of a steam generator device.

MPFA algorithm for solving Stokes–Brinkman equations on quadrilateral grids

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This work is concerned with the development of a robust and accurate numerical method for solving the Stokes-Brinkman system of equations, which describes a free fluid flow coupled with a flow in porous media. Quadrilateral boundary fitted grids with a sophisticated finite volume method, namely MPFA O-method, is used to discretize the system of equations. Numerical results for two examples are presented, namely, channel flow, and flow in a ring with a rolled porous medium.

A model reduction framework for efficient simulation of Li-ion batteries

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In order to achieve a better understanding of degradation processes in lithium-ion batteries, the modeling of cell dynamics at the micrometer scale is an important focus of current mathematical research. These models lead to large-dimensional, highly nonlinear finite volume discretizations which, due to their complexity, cannot be solved at cell scale on current hardware. Model order reduction strategies are therefore necessary to reduce the computational complexity while retaining the features of the model. The application of such strategies to specialized high performance solvers asks for new software designs allowing flexible control of the solvers by the reduction algorithms. In this contribution we discuss the reduction of microscale battery models with the reduced basis method and report on our new software approach on integrating the model order reduction software pyMOR with third-party solvers. Finally, we present numerical results for the reduction of a 3D microscale battery model with porous electrode geometry.

Convergence analysis of a FV-FE scheme for partially miscible two-phase flow in anisotropic porous media

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We study the convergence of a combined finite volume nonconforming finite element scheme on general meshes for a partially miscible two-phase flow model in anisotropic porous media. This model includes capillary effects and exchange between the phase. The diffusion term, which can be anisotropic and heterogeneous, is discretized by piecewise linear nonconforming triangular finite elements. The other terms are discretized by means of a cell-centered finite volume scheme on a dual mesh. The relative permeability of each phase is decentred according the sign of the velocity at the dual interface. The convergence of the scheme is proved thanks to an estimate on the two pressures which allows to show estimates on the discrete time and compactness results in the case of degenerate relative permeabilities. A key point in the scheme is to use particular averaging formula for the dissolution function arising in the diffusion term.We show also a simulation of CO2 injection in a water saturated reservoir and nuclear waste management. Numerical results are obtained by in-house numerical code.

A finite volume method for large-eddy simulation of shallow-water equations

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We present a robust finite volume method for large-eddy simulation of shallow water flows. The governing equations are derived from the Navier–Stokes equations with assumptions of shallow water flows including bed frictions and eddy viscosity. The turbulence effects are incorporated in the system by considering the Smagorinsky model. The numerical fluxes are reconstructed using a modified Roes scheme that incorporates, in its reconstruction, the sign of the Jacobian matrix of the convective part of the large-eddy shallow water equations. The diffusion terms are discretized using a Green–Gauss diamond reconstruction. The propose method is verified for the benchmark problem of flow around a circular cylinder.

Shock capturing for discontinuous Galerkin methods using finite volume sub-cells

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We present a shock capturing procedure for high order discontinuous Galerkin methods, by which shock regions are refined and treated by the finite volume techniques. Hence, our approach combines the good properties of the discontinuous Galerkin method in smooth parts of the flow with the perfect properties of a total variation diminishing finite volume method for resolving shocks without spurious oscillations. Due to the subcell approach the interior resolution on the discontinuous Galerkin grid cell is preserved and the number of degrees of freedom remains the same. In this paper we focus on an implementation of this coupled method and show our first results.

A quasi-1D model of biomass co-firing in a circulating fluidized bed boiler

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We introduce an outline of the mathematical model of combustion in circulating fluidized bed boilers. The model is concerned with multiphase flow of flue gas, bed material, and two types of fuels (coal and biomass) that can be co-fired in the furnace. It further considers phase interaction resulting in particle attrition, devolatilization and burnout of fuel particles, and energy balance between heat production and consumption (radiative and convective transfer to walls). Numerical solution by means of the finite volume method together with a Runge-Kutta class time integration scheme is mentioned only briefly as the used methods are generic and well documented elsewhere. Some representative results are also presented.

An asymptotic-preserving scheme for systems of conservation laws with source terms on 2D unstructured meshes

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A finite volumes numerical scheme is here proposed for hyperbolic systems of conservation laws with source terms which degenerate into parabolic systems in large times when the source terms become stiff. In this framework, it is crucial that the numerical schemes are asymptotic-preserving (AP) it i.e. that they degenerate accordingly. Here, an AP numerical scheme is designed for any system within the aforementioned class on 2D unstructured meshes. This scheme is consistent and stable under a suitable CFL condition. Moreover, we show that it is also possible to prove that it preserves the set of admissible states under a geometrical property on the mesh. Then, numerical examples are given to illustrate its behavior.

A simple well-balanced, positive and entropy-satisfying numerical scheme for the shallow-water system

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This work considers the numerical approximation of the shallow-water equations. In this context, one faces three important issues related to the wellbalanced, non-negativity and entropy-preserving properties, as well as the ability to consider vacuum states. We propose a Godunov-type method based on the design of a three-wave Approximate Riemann Solver (ARS) which satisfies all these properties together.

Piecewise linear transformation in diffusive flux discretizations

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A piecewise linear transformation that allows interpolation of diffused concentration over material discontinuities is presented. It may be used either to evaluate concentration values at auxiliary points, or to approximate face fluxes directly. It does not violate the discrete minimum and maximum principles, so it can be used to construct discretization schemes that preserve solution positivity or discrete minimum and maximum principles. The method has been demonstrated to produce second-order accurate interpolated concentration values and first-order accurate fluxes even when interpolation nodes lie at opposite sides of a discontinuity.

A gradient scheme for the discretization of Richards equation

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We propose a finite volume method on general meshes for the discretization of Richards equation, an elliptic - parabolic equation modeling groundwater flow. The diffusion term, which can be anisotropic and heterogeneous, is discretized in a gradient scheme framework, which can be applied to a wide range of unstructured possibly non-matching polyhedral meshes in arbitrary space dimension. More precisely, we implement the SUSHI scheme which is also locally conservative. As is needed for Richards equation, the time discretization is fully implicit. We obtain a convergence result based upon energy-type estimates and the application of the Fréchet-Kolmogorov compactness theorem. We implement the scheme and present the results of a number of numerical tests.

Coupling of a two phase gas liquid compositional 3D Darcy flow with a 1D compositional free gas flow

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A model coupling a three dimensional gas liquid compositional Darcy flow and a one dimensional compositional free gas flow is presented. The coupling conditions at the interface between the gallery and the porous media account for the molar normal fluxes continuity for each component, the gas liquid thermodynamical equilibrium, the gas pressure continuity and the gas and liquid molar fractions continuity. This model is applied to the simulation of the mass exchanges at the interface between the repository and the ventilation excavated gallery in a nuclear waste geological repository. The convergence of the Vertex Approximate Gradient discretization is analyzed for a simplified model coupling the Richards approximation in the porous media and the gas pressure equation in the gallery.

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9 Gendarmenmarkt

After Wikipedia, the free encyclopedia

Panorama of the Gendarmenmarkt, showing the Konzerthaus, flanked by the German Cathedral (left) and French Cathedral (right)

The “Gendarmenmarkt” is a square in Berlin, and the site of the Konzerthaus and the French and German Cathedrals. In the centre of the square, a monumental statue of Germany’s renowned poet Friedrich Schiller is situated. The square was created by Johann Arnold Nering at the end of the seventeenth century as the Linden-Markt and reconstructed by Georg Christian Unger in 1773. The Gendarmenmarkt is named after the cuirassier regiment Gens d’Armes, which had their stables at the square until 1773.

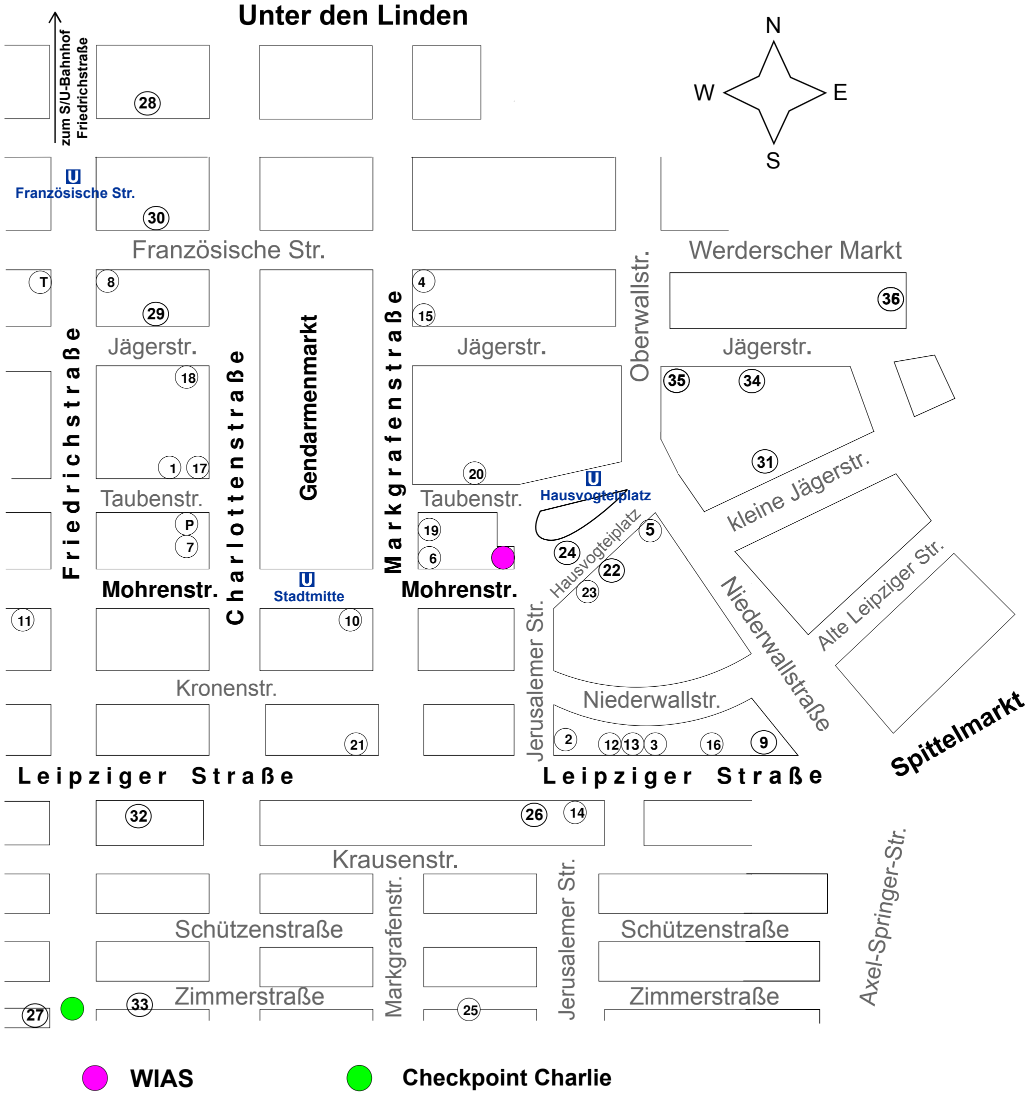
During World War II, most of the buildings were badly damaged or destroyed. Today, all the buildings have been restored to their former state.

The French Cathedral (in German: “Französischer Dom”), the older of the two cathedrals, was built by the Huguenot community between 1701 and 1705. The cathedral was modelled after the destroyed Huguenot church in Charenton-Saint-Maurice, France. The tower and porticoes, designed by Carl von Gontard, were added to the building in 1785. The French cathedral has a viewing platform, a restaurant and a Huguenot museum.

The German Cathedral (in German: “Deutscher Dom”) is located in the south of the Gendarmenmarkt. It has a pentagonal structure and was designed by Martin Grünberg and built in 1708 by Giovanni Simonetti. It too was modified in 1785 by Carl von Gontard, who built the domed tower. The German Cathedral was completely destroyed by fire in 1945, during World War II. After German reunification it was rebuilt, finished in 1993 and re-opened in 1996 as a museum of German history.

The Konzerthaus Berlin is the most recent building on the Gendarmenmarkt. It was built by Karl Friedrich Schinkel in 1821 as the “Schauspielhaus”. It was based on the ruins of the National Theatre, which was destroyed by fire in 1817. Parts of the building contain columns and some outside walls from the destroyed building. Like the other buildings on the square, it was also badly damaged during World War II. The reconstruction, finished in 1984, turned the theatre into a concert hall. Today, it is the home of the Konzerthausorchester Berlin.

10 Lunch



1 Mensa Konzerthaus
2 Bistro Vital
3 Croissanterie "Bistro & Baguette"
4 "Bistro am Gendarmenmarkt"
5 "the coffee shop"
6 KAFFEE EINSTEIN
7 "Foodcourt" in Friedrichstadtpassage
8 "Galéries Lafayette"
9 Viethaus
10 "Hilton"
11 Leopold's Kontorhaus
12 Fontana di Trevi Ristorante
13 Irish Times
14 China-City Restaurant
15 Amici am Gendarmenmarkt
16 "Diverso" Ristorante Italiano
17 Lutter und Wegner
P Post Office

18 Augustiner am Gendarmenmarkt
19 Shan Rahimkan Café
20 Brasserie
21 Löwenbräu
22 Good Time
23 Steinecke
24 farmer's market on Hausvogteiplatz
25 Springer Building
26 Döner / Supermarkt
27 Mc Donalds
28 Subway
29 Guy
30 Borchard
31 Café Laude
32 Tito Vietnamese Food
33 Belegschaft
34 Chipps
35 Feinkost
36 Town Bar
R Reiseland "American Express"