Activity Report 2015

Team SERENA

Simulation for the Environment: Reliable and Efficient Numerical Algorithms

Inria teams are typically groups of researchers working on the definition of a common project, and objectives, with the goal to arrive at the creation of a project-team. Such project-teams may include other partners (universities or research institutions).

RESEARCH CENTER
Paris - Rocquencourt

THEME
Earth, Environmental and Energy Sciences

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Team SERENA

Creation of the Team: 2015 June 01

Keywords:

Computer Science and Digital Science:

2.1.3. - Functional programming
2.4.3. - Proofs
6.1.1. - Continuous Modeling (PDE, ODE)
6.1.5. - Multiphysics modeling
6.2.1. - Numerical analysis of PDE and ODE
6.2.5. - Numerical Linear Algebra

Other Research Topics and Application Domains:

3.1. - Sustainable development
3.3.1. - Earth and subsoil
3.4.3. - Pollution
4.1.1. - Oil, gas
4.1.2. - Nuclear energy

1. Members

Research Scientists

Martin Vohralík [Team leader, Inria, Senior Researcher, HdR]
François Clément [Inria, Researcher]
Michel Kern [Inria, Researcher]
Géraldine Pichot [Inria, Researcher]
Pierre Weis [Inria, Senior Researcher]

Engineers

Alexandre Ern [chief engineer (ENPC)]
Clément Franchini [Inria, granted by OSEO Innovation, until August 31st, 2015]
Laurent Monasse [chief engineer (ENPC)]

PhD Students

Sarah Ali Hassan [Inria]
Nabil Birgle [Inria]
Fatma Cheikh [ENIT-Lamsin, Tunis, Tunisia]
Jad Dabaghi [Inria, from November 2015]
Patrik Daniel [Inria, from October 2015]
Cédric Josz [Inria, granted by CIFRE]
Mohamed Riahi [ENIT-Lamsin, Tunis, Tunisia]

Post-Doctoral Fellows

Elyes Ahmed [Inria]
Iain Smears [Inria, Starting Research position, from September 2015]
Zuqi Tang [Inria, until September 30th, 2015]

Administrative Assistant

Bonte Nathalie [Inria]

Others

Hend Ben Ameur [IPEST and ENIT-Lamsin, Professor, external collaborator, HdR]
Guy Chavent [Univ. Paris-Dauphine, Professor Emeritus, honorary collaborator, HdR]
Jérôme Jaffré [Inria (retired from April 1st, 2015), honorary collaborator, HdR]
Caroline Japhet [Univ. Paris 13, Associate Professor, external collaborator]
Vincent Martin [UTC, Associate Professor, external collaborator]
Jean-Elizabeth Roberts [Inria (retired from April 1st, 2015), honorary collaborator, HdR]

2. Overall Objectives

2.1. Overall Objectives

The team SERENA team is concerned with **numerical methods** for **environmental problems**. The main topics are the conception and analysis of *models* based on *partial differential equations*, the study of their *precise and efficient numerical approximation*, and implementation issues with special concern for *reliability and correctness of programs*. We are in particular interested in the *guaranteeing* the *quality* of the *overall simulation process*. SERENA small shortly become a joint project-team between Inria and ENPC. It has taken over the project-team POMDAPI2 which ended on May 31, 2015.

3. Research Program

3.1. Multiphysics coupling and domain decomposition

Within our project, we start from the conception and analysis of *models* based on *partial differential equations*. Already at the PDE level, we address the question of *coupling* of different models; examples may be that of simultaneous fluid flow in a discrete network of two-dimensional *fractures* and in the surrounding three-dimensional porous medium, or that of interaction of a compressible flow with the surrounding elastic deformable structure. The key physical characteristics need to be captured, whereas existence, uniqueness, and continuous dependence on the data are minimal analytic requirements that we request to satisfy. At the modeling stage, we also plan to develop model-order reduction techniques, such as the use of reduced basis techniques or proper generalized decompositions, to tackle evolutive problems, in particular in the nonlinear case.

We also concentrate an important effort on the development and analysis of efficient solvers for the systems of nonlinear algebraic equations. We have already in the past developed *Newton–Krylov solvers*, with a particular impact on *parallelization* that we achieve via *domain decomposition*. Here we specialize on Robin boundary conditions, where an optimized choice of the parameter has already shown speed-ups in orders of magnitude in terms of the number of the iterations of the domain decomposition algorithm in question. A novel feature is the use of such algorithms in time-dependent problems in *space-time* domain decomposition which allows the use of different time steps in different parts of the computational domain. This is particularly useful in porous media applications, where the amount of diffusion (permeability) varies abruptly, so that the evolution speeds vary importantly and call for adapted localized time stepping. Our other novel theme are *Newton–multigrid solvers*, where the geometric multigrid solver ingredients are *tailored* to the specific problem under consideration and to the specific numerical method, with problem- and discretization-dependent restriction, prolongation, and smoothing. This in particular yields *mass balance* on *each iteration step*, a very welcome feature in most of the target applications. The solver itself is then *steered adaptively* at each execution step by an a posteriori error estimate.

3.2. Structure-preserving discretizations and discrete element methods

Our second important activity is the design of *numerical methods* for the devised partial differential equation model. Traditionally, we have worked in the context of finite element, finite volume, mixed finite element, and discontinuous Galerkin methods. Novel classes of schemes enable the use of general *polygonal* and *polyhedral meshes* with *non-matching interfaces*, and we develop them in response to a high demand from our industrial partners. Our requirement is to derive *structure-preserving* methods, i.e., methods that mimic at the discrete level fundamental properties of the underlying PDEs, such as conservation principles and preservation of invariants. Here, the theoretical questions are closely linked to *differential geometry* for the lowest-order schemes. For the developed schemes, we study the existence, uniqueness, and stability questions, and derive a priori convergence estimates. Our special interest is in higher-order methods, almost nonexisting these days even on the theoretical side. Albeit their use in practice may not be immediate, we believe that they represent the future generation of numerical methods for industrial simulations. These developments are and will be undertaken by Alexandre Ern and Laurent Monasse from ENPC who shall enlarge SERENA in the joint Inria–ENPC team shortly.

3.3. Reliability by a posteriori error control and safe and correct programming

The last part of our theoretical efforts goes towards the certification of the results obtained at the end of the numerical simulation. Here a key ingredient is the development of rigorous *a posteriori error estimates* that enable to estimate in a guaranteed way the error between the unknown exact solution and its numerical approximation. Our estimates also allow to *distinguish* the different *components of the overall error*, namely that coming from the modeling, from the discretization scheme, from the nonlinear (Newton) solver, and from the linear algebraic (Krylov, domain decomposition, multigrid) solver. A novel concept here is that of *local stopping criteria*, where all the error components are balanced locally within each computational mesh element. This naturally interconnects all parts of the numerical simulation process and gives rise to novel *fully adaptive algorithms*. We in particular aim to address the question of convergence of the new algorithms and justify their optimality, proving in particular guaranteed error reduction.

We also concentrate on the issue of computer implementation of scientific computing programs. The increasing complexity of algorithms for modern scientific computing makes it a major challenge to implement them in the traditional imperative languages popular in the community. As an alternative, the computer science community provides theoretically sound tools for *safe* and *correct programming*. In our project, we explore the use of these tools to design generic solutions for the implementation of the considered class of scientific computing software. Our focus ranges from high-level programming via *functional programming* with OCaml, and safe and easy parallelism via *skeleton parallel programming* with Sklml, to proof of correctness of numerical algorithms and programs via *mechanical proofs* with Coq.

4. Application Domains

4.1. Environmental problems

The *applications* of our theoretical results to current challenging *environmental problems* are pursued with numerous *academic collaborators* and with *industrial partners* such as ANDRA, IFP Energies Nouvelles, CEA, and EDF. Our traditional interest goes towards *porous media* for multiphase flows and transport of contaminants in the subsurface, fractures, fracture networks, fractured porous media, subsurface depollution after chemical leakage, nuclear waste disposal in deep underground repositories, and geological sequestration of CO_2. Among our novel themes in the joint team, we will count energy production with in particular fluid mechanics problems arising in the operation of nuclear reactors and shock waves impinging on deformable or fragmentable structures; in these cases, complex Euler or Navier–Stokes flows appear, and the modeling of the interacting mechanical structure is crucial.

5. Highlights of the Year

5.1. Highlights of the Year

5.1.1. Awards

Martin Vohralík obtained the ERC consolidator grant in the 2015 campaign with his project GATIPOR "Guaranteed fully adaptive algorithms with tailored inexact solvers for complex porous media flows".

Jérôme Jaffré was awarded the 2015 SIAM Geosciences Senior Career Prize.

6. New Software and Platforms

6.1. New Software

6.1.1. FreeFem++ a posteriori package

Participants: Martin Vohralík, Zuqi Tang.

The scientific calculation code FreeFem++ is an example of a complex software numerical simulation tool relying on traditional matching triangular meshes. It encompasses all specification of the problem, the choice and implementation of the numerical method, the choice and implementation of the linearization method (nonlinear solver), and the choice and implementation of the method of solution of the associated linear systems (linear solver). In the post-doc stay of Z. Tang, we have integrated here some recent advances of the theory of a posteriori error estimation and of adaptive algorithms. In particular, (local) adaptive stopping criteria for the linear and nonlinear solvers have been implemented.

Version 3.42

Programming language: C++

http://www.freefem.org/ff++/

https://who.rocq.inria.fr/Zuqi.Tang/freefem++.html

7. New Results

7.1. Guaranteed bounds for Laplace eigenvalues and eigenvectors

In [22], we have derived a posteriori error estimates for the Laplace eigenvalue problem. Guaranteed, fully computable, and optimally convergent upper and lower bounds for the first eigenvalue are given. They are valid under explicit, a posteriori conditions on the computational mesh and on the approximate solution. Guaranteed, fully computable, and polynomial-degree robust bounds for the energy error in the approximation of the first eigenvector are derived as well, under the same conditions. Remarkably, all the constants in our theory can be fully estimated, and no convexity/regularity assumption on the computational domain/exact eigenvector(s) is needed. This general result can still be improved when an elliptic regularity assumption is satisfied (with known constants), typically for convex two-dimensional domains. The application of our framework to conforming finite element approximations of arbitrary polynomial degree is provided, along with a numerical illustration on a set of test problems.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

A one-year contract with the IFP Energies Nouvelles department of Applied mathematics on "Etudes d'estimations d'erreur a posteriori sur des maillages généraux" ("Study if a posteriori error estimates on general meshes) within the *contrat-cadre* between Inria and IFP Energies Nouvelles has been concluded and started.

8.2. Bilateral Grants with Industry

ANDRA is funding the Ph.D. thesis of S. Ali Hassan (an agreement that is part of an *accord cadre* between Inria and ANDRA).

9. Partnerships and Cooperations

9.1. Regional Initiatives

GT Elfic (Labex DigiCosme, 2014–2016): "Programmes d'éléments finis formellement vérifiés", with TOCCATA (Inria Saclay - Île-de-France), CEA LIST, LIPN (Université de Paris 13), and LMAC (Université de Technologie de Compiègne).

The research on a posteriori error estimates, unified frameworks, robustness, adaptivity, and stopping criteria of M. Vohralík was carried out with Alexandre ERN from CERMICS, Ecole Nationale des Ponts et Chaussées, see [14], [24].

A posteriori error estimates for eigenvalue problems were derived in collaboration with Geneviève DUSSON, Yvon MADAY, and Benjamin STAMM from the Laboratoire Jacques-Louis Lions and Eric CANCÈS, CERMICS, see [21] and [22].

A posteriori error estimates for problems with sign-changing coefficients describing electromagnetism for interfaces between dielectrics and negative metamaterials have been derived in collaboration with P. Ciarlet from the project-team POEMS, see [23].

9.2. National Initiatives

9.2.1. ANR

ANR GEOPOR: "Geometrical approach for porous media flows: theory and numerics", with Laboratoire Jacques-Louis Lions (University Paris VI).

ANR MANIF: "Mathematical and numerical issues in first-principle molecular simulation", with CERMICS (Ecole Nationale des Ponts et Chaussées), and Laboratoire Jacques-Louis Lions (University Paris VI).

ANR DEDALES; "Algebraic and Geometric Domain Decomposition for Subsurface Flow". The project aims at developing high performance software for the simulation of two phase flow in porous media. The project will specifically target parallel computers where each node is itself composed of a large number of processing cores, such as are found in new generation many-core architectures.

The partners are HIEPACS, Laboratoire Analyse, Géométrie et Application, Maison de la Simulation, and ANDRA. The coordiinator of the project is M. Kern.

C2S@Exa (Computer and Computational Sciences at Exascale) is an Inria Project Lab (IPL). This national initiative aims at the development of numerical modeling methodologies that fully exploit the processing capabilities of modern massively parallel architectures in the context of a number of selected applications related to important scientific and technological challenges for the quality and the security of life in our society. This project supports in particular the Ph.D. of N. Birgle (supervised by. J. Jaffré) which is part of an Inria-Andra collaboration.

9.2.2. FUI

Projet P (2011–2015) is funded by the French FUI (*Fonds Unique Interministériel*). Project P aims at supporting the model-driven engineering of high-integrity embedded real-time systems by providing an open code generation framework. The contribution of team Serena is in the domain of language translation and block-schema modelization semantics. This project supports the work of C. Franchini, under the supervision of P. Weis.

9.3. European Initiatives

9.3.1. Collaborations in European Programs, except FP7 & H2020

Program: Research, Development and Innovation Council of the Czech Republic

Project acronym: MORE

Project title: Implicitly constituted material models: from theory through model reduction to efficient numerical methods

Duration: September 2012 – September 2017

Coordinator: Josef MÁLEK, Charles University in Prague

Other partners: Institute of Mathematics, Academy of Sciences of the Czech Republic; Oxford Centre for Nonlinear Partial Differential Equations, Great Britain.

Abstract: A multidisciplinary project on nonlinear Navier–Stokes flows with implicit constitutive laws. It focuses on development of accurate, efficient, and robust numerical methods for simulations of the new class of implicit models, see http://more.karlin.mff.cuni.cz/.

9.4. International Initiatives

9.4.1. Participation In International Programs

Serena is part of the EuroMediterranean 3+3 program with the project HYDRINV (2012–2015): Direct and inverse problems in subsurface flow and transport. Besides Inria, institutions participating in this project are: Universitat Politècnica de Catalunya (Barcelona, Spain), Universidad de Sevilla (Spain), École Mohamedia d'Ingénieurs (Rabat, Morocco), Université Ibn Tofaïl (Kenitra, Morocco), University Centre of Khemis Miliana (Algeria), and École Nationale d'Ingénieurs de Tunis (Tunisia).

9.5. International Research Visitors

9.5.1. Visits of International Scientists

Josef Málek, professor, Mathematical Institute, Charles University in Prague. February 2–6, 2015.

Iuliu Sorin Pop, professor, Department of Mathematics and Computer Science, Eindhoven University of Technology. March 2–6, 2015.

H. Ben Ameur, professor at IPEST and member of ENIT-Lamsin, Tunis, Tunisia. November 9–20, 2015.

Carol Woodward, computational mathematician in the Center for Applied Scientific Computing (CASC) at Lawrence Livermore National Laboratory, USA, December 4, 2015.

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific events organisation

10.1.1.1. Member of the organizing committees

M. Vohralík co-organizes, together with Irène Vignon-Clementel from the project-team REO, the monthly *Modeling and Scientific Calculation Seminar* of the Inria Paris-Rocquencourt research centre, see the web page https://iww.inria.fr/modelisation_et_calcul_scientifique/en/.

10.1.2. Scientific events selection

10.1.2.1. Member of the conference program committees

M. Kern and M. Vohralík both served on the Scientific Committee of *SimRace, Conference on numerical methods and High Performance Computing for industrial fluid flows* http://www.rs-simrace.com/ in 2015. M. Vohralík served in the scientific committee of *ENUMATH 2015* http://enumath2015.iam.metu.edu.tr/.

10.1.3. Journal

10.1.3.1. Member of the editorial boards

M. Vohralík is a member (from December 2013) of the editorial board of *SIAM Journal on Numerical Analysis*, see http://www.siam.org/journals/sinum/board.php.

10.1.3.2. Reviewer - Reviewing activities

G. Pichot served as a reviewer for Journal of Computational Physics.

M. Kern served as a reviewer for the journals *Electronic Transactions on Numerical Analysis*, *Computational Geosciences*, *Transport in Porous Media*, and *Oil & Gas Science and Technology*.

M. Vohralík served as a reviewer for *SIAM Journal on Numerical Analysis*, *Mathematics of Computation*, *Numerische Mathematik*, *Computer Methods in Applied Mechanics and Engineering*, *SIAM Journal on Scientific Computing*, *M2AN. Mathematical Modelling and Numerical Analysis*, *Numerical Methods for Partial Differential Equations*, *IMA Journal of Numerical Analysis*, and *Comptes rendus de l'Académie des sciences (mathématique)*, as well as for *Mathematical Reviews* of the American Mathematical Society.

10.1.4. Invited talks

"The current landscape of energy a posteriori error estimators", 29 September 2015, 28th Chemnitz FEM symposium, Germany, by M. Vohralík.

"Polynomial-degree-robust a posteriori estimates in a unified setting", 14 January 2015, 8th Chilean Numerical Analysis and Partial Differential Equations Meeting, La Serena, Chile, by M. Vohralík.

"Discrete reduced models for flow in porous media with faults and barriers", 30 June 2015, SIAM Geosciences (GS15), Stanford, June 29 - July 2, 2015. This lecture was given at the award ceremony for the SIAM Geosciences Senior Career prize awarded to Jérôme Jaffré.

"Global in time domain decomposition methods for flow and transport in porous media", 16 Ocotbre 2015, ENIT LAMSIN, Tunis, M. Kern

10.1.5. Scientific expertise

J. E. Roberts is a member of the External Advisory Board for CFSES (Center for Frontiers of Subsurface Energy Security), University of Texas at Austin and SANDIA National Laboratories, Albuquerque, New Mexico.

J. E. Roberts is a member of the selection committee for recruiting professors in the department of maths of the University of Bergen, and a member of the national Norwegian committee for the promotion of professors.

M. Kern is a member of the Scientific Committee of Orap (ORganisation Associative du Parallélisme), of the Scientific Board of GDR Calcul, and of the jury and executive board of Label C3I.

10.1.6. Research administration

F. Clément is the *correspondant Inria-entreprise* of the center of Paris-Rocquencourt for AMIES (from September 2015).

G. Pichot is member of the Conseil de département MAM of Polytech Lyon.

M. Kern is the Deputy Director of Maison de la Simulation, a joint project between CEA, CNRA, Inria, Université de Paris 11, and Unversité de Versailles, focused on applications of high end computing.

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Master : M. Vohralík, *A posteriori error estimates for efficiency and error control in numerical simulations*, 36 hours/year, 2nd year master, Laboratoire Jacques-Louis Lions (University Paris VI), France.

Master : M. Vohralík, *A posteriori error estimates for efficiency and error control in numerical simulations*, 36 hours/year, 2nd year master, Department of Numerical Mathematics, Charles University in Prague, Czech Republic.

Doctorat: M. Kern, *Méthodes numériques pour les problèmes inverses*, 18 hours, ENIT, Tunis

Master: M. Kern, *Modélisation et simulation des écoulements de fluides dans la géosphère*, 18 hours/year, 2nd year master "Mathématiques et Applications" (parcours Analyse, Modélisation et Simulation), Université Paris Saclay, France

École d'Ingénieurs: M. Kern, *Éléments finis* (avec D. Ryckelynck), *Problèmes inverses*, 40 hours/year, 2nd year students, École Mines-ParisTech, France.

10.2.2. Supervision

PhD: L. Lenôtre, University of Rennes 1, November 2015, co-advisors A. Lejay (Inria Nancy) and G. Pichot, with J. Erhel.

PhD in progress: S. Ali Hassan, *Estimations d'erreur a posteriori et critères d'arrêt pour des solveurs par décomposition de domaine et avec des pas de temps locaux* (*A posteriori error estimates and stopping criteria for domain decomposition solvers with local time stepping*), University Paris VI, November 2013, advisor M. Vohralík, co-advisors C. Japhet and M. Kern.

PhD in progress: P. Daniel, *Adaptive multilevel solvers with a posteriori error control for porous media flows*, University Paris VI, October 2015, advisor M. Vohralík, co-advisor A. Ern.

PhD in progress: J. Dabaghi, *Modélisations adaptives par complémentarité d'apparition et de disparition de phases en milieux poreux et fracturés* (*Adaptive modeling via complementarity of phase appearance and disappearance in fractured and porous media*), University Paris VI, November 2015, advisor M. Vohralík, co-advisor V. Martin.

PhD in progress : N. Birgle, *Écoulements souterrains, méthodes numériques, et calcul haute performance*, University Paris VI, October 2012, advisor J. Jaffré, co-advisor J. E. Roberts.

PhD in progress : F. Cheikh, *Identification de failles dans un milieu poreux par une méthode d'indicateurs*, University Paris VI and University of Tunis El Manar, December 2011, advisors J. E. Roberts and H. Ben Ameur, co-advisors V. Martin and F. Clément.

PhD : E. Ahmed, *Décomposition de domaines pour quelques problèmes de transmission des fluides dans les milieux poreux : Applications en hydrogéologie et en biologie* , University of Tunis El Manar, ENIT-LAMSIN, Defended on April 30, Advisors J. Jaffré, J. E. Roberts and A. Ben Abda.

PhD in progress : M. H. Riahi, *Identification de paramètres hydrogéologiques dans un milieu poreux*, University Paris VI and University of Tunis El Manar, December 2011, advisors J. Jaffré and H. Ben Ameur.

10.2.3. Juries

F. Clément was member of the PhD thesis committee of Julien-Pierre Offret, Université Paris Ouest Nanterre La Défense (December 2nd, 2015).

M. Kern was member of the PhD thesis committees of

- Zifan Liu, Université de Versailles (January 2015);
- Thomas Applencourt, université de Toulouse (November 2015);
- Rudi Leroy, université de Lille (December 2015).

[1] [2] [3] [4] [5] [6] [7] [8] [9] [10]

11. Bibliography

Major publications by the team in recent years

[1] S. BOLDO, F. CLÉMENT, J.-C. FILLIÂTRE, M. MAYERO, G. MELQUIOND, P. WEIS. *Wave equation numerical resolution: a comprehensive mechanized proof of a C program*, in "Journal of Automated Reasoning", April 2013, vol. 50, n^{o} 4, pp. 423–456, http://dx.doi.org/10.1007/s10817-012-9255-4

[2] S. BOLDO, F. CLÉMENT, J.-C. FILLIÂTRE, M. MAYERO, G. MELQUIOND, P. WEIS. *Trusting computations: A mechanized proof from partial differential equations to actual program*, in "Computers and Mathematics with Applications", August 2014, vol. 68, n^{o} 3, pp. 325–352, http://dx.doi.org/10.1016/j.camwa.2014.06.004

[3] D. A. DI PIETRO, M. VOHRALÍK, S. YOUSEF. *Adaptive regularization, linearization, and discretization and a posteriori error control for the two-phase Stefan problem*, in "Math. Comp.", 2015, vol. 84, n^{o} 291, pp. 153–186, http://dx.doi.org/10.1090/S0025-5718-2014-02854-8

[4] A. ERN, M. VOHRALÍK. *Adaptive inexact Newton methods with a posteriori stopping criteria for nonlinear diffusion PDEs*, in "SIAM J. Sci. Comput.", 2013, vol. 35, n^{o} 4, pp. A1761–A1791, http://dx.doi.org/10.1137/120896918

[5] T.-T.-P. HOANG, J. JAFFRÉ, C. JAPHET, M. KERN, J. E. ROBERTS. *Space-time domain decomposition methods for diffusion problems in mixed formulations*, in "SIAM J. Numer. Anal.", 2013, vol. 51, n^{o} 6, pp. 3532–3559, http://dx.doi.org/10.1137/130914401

[6] T. HOANG, C. JAPHET, M. KERN, J. E. ROBERTS. *Space-time Domain Decomposition and Mixed Formulation for solving reduced fracture models*, in "SIAM J. Numer. Anal.", 2015, accepted for publication

[7] A. LEJAY, G. PICHOT. *Simulating diffusion processes in discontinuous media: a numerical scheme with constant time steps*, in "J. Comput. Phys.", 2012, vol. 231, n^{o} 21, pp. 7299–7314, http://dx.doi.org/10.1016/j.jcp.2012.07.011

[8] G. PICHOT, J. ERHEL, J.-R. DE DREUZY. *A generalized mixed hybrid mortar method for solving flow in stochastic discrete fracture networks*, in "SIAM J. Sci. Comput.", 2012, vol. 34, n^{o} 1, pp. B86–B105, http://dx.doi.org/10.1137/100804383

[9] M. VOHRALÍK, M. F. WHEELER. *A posteriori error estimates, stopping criteria, and adaptivity for two-phase flows*, in "Comput. Geosci.", 2013, vol. 17, n^{o} 5, pp. 789–812, http://dx.doi.org/10.1007/s10596-013-9356-0

[10] M. VOHRALÍK, B. I. WOHLMUTH. *Mixed finite element methods: implementation with one unknown per element, local flux expressions, positivity, polygonal meshes, and relations to other methods*, in "Math. Models Methods Appl. Sci.", 2013, vol. 23, n^{o} 5, pp. 803–838, http://www.worldscientific.com/doi/abs/10.1142/S0218202512500613

Publications of the year

Articles in International Peer-Reviewed Journals

[11] E. AHUSBORDE, M. KERN, V. VOSTRIKOV. *Numerical simulation of two-phase multicomponent flow with reactive transport in porous media: application to geological sequestration of CO2*, in "ESAIM: Proceedings and Surveys", March 2015, vol. 50, pp. 21 - 39 [*DOI :* 10.1051/PROC/201550002], https://hal.inria.fr/hal-01133858

[12] A. CHICHE, J. C. GILBERT. *How the augmented Lagrangian algorithm can deal with an infeasible convex quadratic optimization problem*, in "Journal of Convex Analysis", 2015, vol. 4, 30 p. , https://hal.inria.fr/hal-01111126

[13] P. DULAR, Y. LE MENACH, Z. TANG, E. CREUSÉ, F. PIRIOU. *Finite element mesh adaptation strategies from residual and hierarchical error estimators in eddy current problems*, in "IEEE Transactions on Magnetics", 2015, vol. 51, n^o 3 [*DOI :* 10.1109/TMAG.2014.2352553], https://hal.archives-ouvertes.fr/hal-01243654

[14] A. ERN, M. VOHRALÍK. *Polynomial-degree-robust a posteriori estimates in a unified setting for conforming, nonconforming, discontinuous Galerkin, and mixed discretizations*, in "SIAM Journal on Numerical Analysis", April 2015, vol. 53, n^o 2, pp. 1058–1081, https://hal.inria.fr/hal-00921583

[15] Z. TANG, Y. LE MENACH, E. CREUSÉ, S. NICAISE, F. PIRIOU, N. NEMITZ. *A posteriori residual error estimators with mixed boundary conditions for quasi-static electromagnetic problems*, in "COMPEL: The International Journal for Computation and Mathematics in Electrical and Electronic Engineering", 2015, vol. 34, n^o 3, pp. 724-739 [*DOI :* 10.1108/COMPEL-10-2014-0256], https://hal.archives-ouvertes.fr/hal-01243637

[16] Z. TANG, Y. LE MENACH, E. CREUSÉ, S. NICAISE, F. PIRIOU. *Residual a posteriori estimator for magnetoharmonic potential formulations with global quantities source terms*, in "IEEE Transactions on Magnetics", 2015, vol. 51, n^o 3 [*DOI :* 10.1109/TMAG.2014.2359770], https://hal.archives-ouvertes.fr/hal-01243666

Conferences without Proceedings

[17] E. AHMED, J. JAFFRÉ, J. E. ROBERTS. *A 3-D reduced fracture model for two-phase flow in porous media with a global pressure formulation*, in "MAMERN VI", Pau, France, June 2015, https://hal.inria.fr/hal-01119986

Research Reports

[18] M. H. RIAHI, H. BEN AMEUR, R. BOUHLILA, J. JAFFRÉ. *Refinement indicators for optimal parameterization in the estimation of hydrogeological coefficients*, Inria Paris-Rocquencourt ; Université de Tunis El Manar, ENIT-LAMSIN, December 2015, n^o RR-8791, 30 p. , https://hal.inria.fr/hal-01254165

Other Publications

[19] E. AHMED, J. JAFFRÉ, J. E. ROBERTS. *A reduced fracture model for two-phase flow with different rock types*, November 2015, working paper or preprint, https://hal.inria.fr/hal-01249322

[20] N. BIRGLE, J. JAFFRÉ, J. E. ROBERTS. *A 2-D Composite Polygonal Mixed Finite Element*, December 2015, working paper or preprint, https://hal.inria.fr/hal-01251652

[21] E. CANCÈS, G. DUSSON, Y. MADAY, B. STAMM, M. VOHRALÍK. *A perturbation-method-based post-processing for the planewave discretization of Kohn–Sham models*, October 2015, working paper or preprint, http://hal.upmc.fr/hal-01140818

[22] E. CANCÈS, G. DUSSON, Y. MADAY, B. STAMM, M. VOHRALÍK. *Guaranteed and robust a posteriori bounds for Laplace eigenvalues and eigenvectors: conforming approximations*, September 2015, working paper or preprint, https://hal.inria.fr/hal-01194364

[23] P. CIARLET, M. VOHRALÍK. *Robust a posteriori error control for transmission problems with sign-changing coefficients using localization of dual norms*, May 2015, working paper or preprint, https://hal.inria.fr/hal-01148476

[24] V. DOLEJŠÍ, A. ERN, M. VOHRALÍK. *hp-adaptation driven by polynomial-degree-robust a posteriori error estimates for elliptic problems*, June 2015, working paper or preprint, https://hal.inria.fr/hal-01165187

[25] I. FAILLE, A. FUMAGALLI, J. JAFFRÉ, J. ROBERTS. *Reduced models for flow in porous media containing faults with discretization using hybrid finite volume schemes*, June 2015, working paper or preprint, https://hal-ifp.archives-ouvertes.fr/hal-01162048

[26] J. C. GILBERT. *Advanced Continuous Optimization*, September 2015, Lecture, https://hal.inria.fr/cel-01249369

[27] T.-T.-P. HOANG, C. JAPHET, M. KERN, J. E. ROBERTS. *Space-time Domain Decomposition and Mixed Formulation for solving reduced fracture models*, February 2015, working paper or preprint, https://hal.inria.fr/hal-01113953