Domain Decomposition Methods in Science and Engineering XXI

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Springer

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Preface of DD21 Book of Proceedings

The proceedings of the 21st International Conference on Domain Decomposition Methods contain the definitive technical record of advances in the analysis, algorithmic development, large-scale implementation, and application of domain decomposition methods in science and engineering up to 2012. The conference was hosted by the Inria Rennes center in France, June 25–29, 2012, and was organized jointly by the team Sage of Inria at Rennes (Brittany) and the team LMNO at the University of Caen (Normandy). It represents the largest meeting to this date, with 260 participants, mainly from Europe, but also from America, Asia, and Africa.

Background of the Conference Series

The International Conference on Domain Decomposition Methods has been held in 13 countries throughout Asia, Europe, and North America, beginning in Paris in 1987. Held annually for the first 14 meetings, it is spaced out since DD15 at roughly 18-month intervals. A complete list of the past meetings appears below. The twenty-first International Conference on Domain Decomposition Methods was the third one held in France, after DD1 in Paris in 1987 and DD13 in Lyon in 2000.

The main technical content of the DD conference series has always been mathematical, but the principal motivation is to make efficient use of distributed memory computers for complex applications arising in science and engineering. Thus, contributions from mathematicians, computer scientists, engineers, and scientists have always been welcome. While domain decomposition methods are nowadays very important for the efficient simulation of large-scale applications on massively parallel processors, there are also many interesting applications of domain decomposition that are not massively parallel. For example, connecting just two subproblems to effectively exploit a different solver on each is also a core area of research visible in this conference, and the same holds for coupling problems like fluid structure interaction. Especially as multiprocessing becomes commonplace, multiphysics modeling is in ascendancy, so the International Conference on Domain

Decomposition Methods remains as relevant and as fundamentally interdisciplinary as ever. While research in domain decomposition methods is presented at numerous venues, the International Conference on Domain Decomposition Methods is the only regularly occurring international forum dedicated to interdisciplinary technical interactions between theoreticians and practitioners working in the creation, analysis, software implementation, and application of domain decomposition methods.

International Conferences on Domain Decomposition Methods

1. Paris, France, January 7–9, 1987
2. Los Angeles, USA, January 14–16, 1988
3. Houston, USA, March 20–22, 1989
4. Moscow, USSR, May 21–25, 1990
5. Norfolk, USA, May 6–8, 1991
6. Como, Italy, June 15–19, 1992
7. University Park, Pennsylvania, USA, October 27–30, 1993
8. Beijing, China, May 16–19, 1995
9. Ullensvang, Norway, June 3–8, 1996
10. Boulder, USA, August 10–14, 1997
11. Greenwich, UK, July 20–24, 1998
12. Chiba, Japan, October 25–29, 1999
13. Lyon, France, October 9–12, 2000
14. Cocoyoc, Mexico, January 6–11, 2002
15. Berlin, Germany, July 21–15, 2003
16. New York, USA, January 12–15, 2005
17. St. Wolfgang-Strobl, July 3–7, Austria 2006
18. Jerusalem, Israel, January 12–17, 2008
19. Zhangjiajie, China, August 17–22, 2009
20. San Diego, California, February 7–11, 2011
21. Rennes, France, June 25–29, 2012

International Scientific Committee on Domain Decomposition Methods

- Petter Bjørstad, University of Bergen, Norway
- Susanne Brenner, Louisiana State University, USA
- Martin Gander, University of Geneva, Switzerland
- Roland Glowinski, University of Houston, USA
- Laurence Halpern, University Paris 13, France
- Ronald Hoppe, Universities of Augsburg, Germany, and Houston, USA

- David Keyes, KAUST, Saudi Arabia
- Hyea Hyun Kim, Kyung Hee University, Korea
- Ralf Kornhuber, Freie Universität Berlin, Germany
- Ulrich Langer, University of Linz, Austria
- Alfio Quarteroni, EPFL, Switzerland
- Olof Widlund, Courant Institute, USA
- Jinchao Xu, Penn State, USA
- Jun Zou, Chinese University of Hong Kong

About the Twenty-First Conference

The conference, which was organized over an entire week, featured 237 presentations of three different types:

- 14 invited plenary talks: selected by the International Scientific Committee from about three times this number of nominees by the International Scientific Committee;
- 153 talks invited by minisymposia organizers, arranged around a special topic, and grouped into 20 minisymposia;
- 70 contributed talks, grouped into 21 sessions.

The shear size of the 21st conference required for the first time four or five parallel sessions, which, while being a huge success for the conference series, made it not easy for the participants to attend all the talks they were interested in. All the presentations are gathered in the book of abstracts, which is available online at http://dd21.inria.fr/downloads/dd21-abstracts.pdf.

The present proceedings volume contains a selection of 94 papers, split into 11 plenary papers, 48 minisymposia papers, and 35 contribution papers.

Sponsoring Organizations

- Laboratoire de Mathématiques Nicolas Oresme (LMNO)
- University of Caen Basse Normandie (UCBN)
- CNRS, Fédération Normandie Mathématiques
- Inria
- University of Rennes 1
- IRMAR
- INSA Rennes
- RISC-E
- ERC
- Fondation Michel Métivier
- Rennes city council

- Rennes metropole council
- Brittany council
- Ministère de l'Enseignement Supérieur et de la Recherche
- Cerfacs
- Maison de la simulation
- Hutchinson

Cooperating Organizations

- IRISA
- ENS Rennes
- SMAI
- MICADO

Local Organizing Committee Members

- Jocelyne Erhel—Co-chair—Inria Rennes
- Taoufik Sassi—Co-chair—University of Caen
- Léonardo Baffico—University of Caen
- Alain Campbell—University of Caen
- Edouard Canot—IRISA, Rennes
- Christian Dogbe—University of Caen
- Caroline Japhet—University of Paris 13 and Inria Paris
- Géraldine Pichot—Inria Rennes
- Edith Blin—Project Manager—Inria Rennes
- Fabienne Cuyollaa—Assistant—Inria Rennes
- Nadir Soualem—Webmaster—Inria Rennes

Social events included a welcoming reception at the Rennes city hall and an excursion to Mont-Saint-Michel, which is listed UNESCO World Heritage site, and which is at the interface between Brittany and Normandy, concluded by a gala dinner in Normandy. The plenary speakers were invited for dinner by the local organizing committee.

The organizing committee would like to thank Inria staff for the practical help, the French community of DD involved in the program committee, and the sponsors for the financial support.

Research Activity in Domain Decomposition According to DD21 and Its Proceedings

We now take a look at the current research activities in domain decomposition methods by taking a closer look at the content of the DD21 conference and the present proceedings. The conference and the proceedings contain three parts: the plenary presentations, the minisymposia presentations and the contributed talks.

Plenary Presentations

The plenary presentations are selected by the scientific committee, and thus reflect in some sense the core interest of this committee. In DD21, there were 14 plenary talks, and 11 speakers submitted a paper to the proceedings. Each paper covers quite a different aspect of domain decomposition methods, and it is not easy to group them.

There are three papers dealing with domain decomposition methods in the presence of DG discretizations. One is focusing on non-overlapping Schwarz and two main classes of space decompositions, the second on FETI-DP preconditioners where jumps and non-conforming meshes are allowed only between subdomains, and the last one on coupling between DG and finite volume methods in the context of hydrocarbon transport in reservoirs.

There are also three papers with a focus more on a particular application: one paper is dedicated to a new finite element discretization for particulate flow, which has the advantage that only few modifications are needed in an existing Navier–Stokes solver to simulate particle transport. The second one proposes the use of mortar methods for discrete fracture networks in a BDD setting, and the last one proposes an efficient MPI implementation of an auxiliary subspace preconditioner for solving a black oil model.

Two papers address coarse spaces and multiscale problems: the first one presents adaptive coarse spaces for FETI for nonlinear problems, and the second one, whose main focus is on multiscale problems, shows that for FETI and TFETI standard coarse spaces can be used, in contrast to Schwarz methods, which need sophisticated coarse spaces in the presence of multiscale phenomena for robust convergence.

There is only one paper dedicated to time-dependent problems. Its focus is on optimized Schwarz waveform relaxation methods for nonlinear parabolic problems. Coefficients are optimized using asymptotic analysis for a linearized system of advection reaction diffusion equations, and then tested in the nonlinear setting.

In one paper, a new domain decomposition method is proposed for integral equations. It is based on a local multitrace formulation, for which well posedness is shown under certain hypotheses, and also a relaxation is proposed based on optimized Schwarz theory.

Another paper is dedicated to domain decomposition methods for the Stokes problem. A general framework is presented, in which primal and dual substructuring formulations are analyzed, and condition number estimates are given.

Minisymposia

There were 20 minisymposia organized within DD21:

1. Finite element packages with domain decomposition solvers (Frederic Hecht, Frederic Nataf and Christophe Prud'Homme)
2. Domain decomposition for porous media flow and transport (Caroline Japhet and Michel Kern)
3. Finite elements for first-order system formulations of interface problems (Gerhard Starke and Pavel Bochev)
4. On the origins of domain decomposition methods (Martin Gander)
5. Exotic coarse spaces for domain decomposition methods (Martin Gander, Laurence Halpern and Kevin Santugini)
6. Heterogeneous domain decomposition methods (Marco Discacciati and Oliver Sander)
7. Domain decomposition, preconditioning and solvers in Isogeometric Analysis (Lourenco Beirao Da Veiga, Michel Bercovier and Simone Scacchi)
8. Domain decomposition techniques in practical flow applications (Menno Genseberger, Mart Borsboom and Martin Gander)
9. Fast solvers for Helmholtz and Maxwell equations (Victorita Dolean, Ronan Perrussel, Hui Zhang and Peng Zhen)
10. New developments of FETI, BDDC, and related domain decomposition methods (Xuemin Tu and Olof Widlund)
11. Decomposition strategies for Boltzmann's equation (Heiko Berninger and Jérôme Michaud)
12. Domain decomposition techniques in life science modeling and simulation (Luca Gerardo Giorda and Victorita Dolean)
13. Robust multilevel methods for multiscale problems (Thomas Dufaud, Johannes Kraus, Clemens Pechstein, Robert Scheichl and Jörg Willems)
14. 100% parallelizable algorithms for symmetric, indefinite and non-symmetric problems (Ismael Herrera)
15. Space-time parallel methods (Martin Gander and Felix Kwok and Yvon Maday)
16. Domain decomposition with mortars (Yvon Maday and Caroline Japhet)
17. Domain decomposition methods based on Robin conditions for large and/or nonlinear problems (Sebastien Loisel, Heiko Berninger and Oliver Sander)
18. Solvers for discontinuous Galerkin methods (Blanca Ayuso de Dios and Susanne C. Brenner)
19. Domain decomposition in computational cardiology (Rolf Krause and Luca Pavarino)
20. Domain decomposition and multiscale methods (Petter Bjørstad)

We see that the minisymposia are focusing either on a particular application (porous media, interface problems and heterogeneous DD methods, flow problems, Helmholtz and Maxwell equations, Boltzmann, life science, multiscale problems, cardiology), or on a particular domain decomposition or dicretization technique (exotic coarse spaces, FETI and BDDC, time decomposition, mortar, optimized transmission conditions, isogeometric methods, multilevel methods). There are two special minisymposia as well, one on the history of domain decomposition methods, and the other on FEM packages with DD solvers.

The papers submitted to the minisymposia part of the proceedings also reflect this mix between application focused contributions and domain decomposition focused contributions. Substantial new results can be found on coarse spaces, optimized transmission conditions, in particular on Helmholtz and Maxwell problems, new methods for evolution problems which solve directly in space time, and time parallel methods. There are also two historical papers tracing in detail the invention of the overlapping Schwarz method, and the invention of substructuring or Schur complement methods.

Contributed Presentations

The proceedings part with contributed presentations is a real treasure trove for new ideas in domain decomposition methods: there are many innovative techniques for time decomposition methods and time parallelism, and various applications, ranging from power systems and Coulomb friction, over image processing to gravimetry and CAD-based domain decomposition. There are also several contributions on well-established domain decomposition methods, like FETI and FETI DP, and optimized Schwarz methods.

Domain Decomposition Methods in the Future

The present proceedings volume is a testimony that domain decomposition is a vibrant, active field of research, even though it has become mature over the last decade. There are three driving forces really that push this field forward:

1. The interest of mathematicians to develop and analyze new methods of domain decomposition type.
2. The many fields of applications which use in addition to the two classical principles of theory and physical experiment to drive science forward also the computational experiment.
3. The ubiquitous availability of multicore computers, a trend which will only continue to last.

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