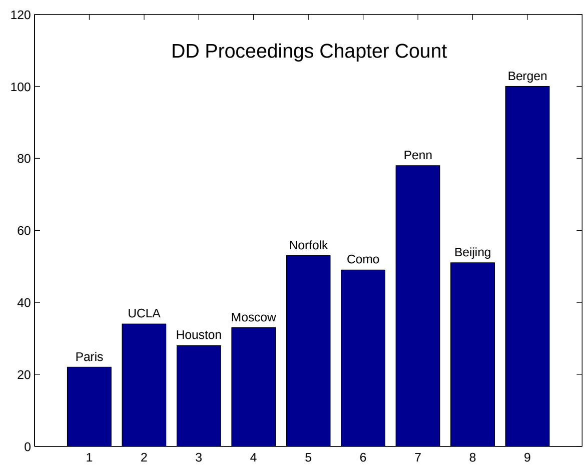
Preface

This volume captures about three-fourths of the proceedings of the Ninth International Conference on Domain Decomposition Methods, which was hosted by the University of Bergen in the resort village of Ullensvang, Norway, June 3–8, 1996. Approximately 180 mathematicians, engineers, physical scientists, and computer scientists from 21 countries came to this annual gathering.

Since three parallel sessions were employed at the conference in order to accommodate as many presenters as possible, attendees and non-attendees alike may turn to this volume to keep up with the diversity of subject matter that the umbrella "domain decomposition" inspires throughout the community. Its contributors are to be commended for their efforts to write for a diverse audience while staying within eight pages. Page quotas are essential to accommodate by far the largest title count in the nine-volume history of the conference.



The interest of so many authors in meeting the editorial demands and page limitations of this proceedings volume resoundingly resolves the annual and proper

Ninth International Conference on Domain Decomposition Methods
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question of whether the common thread of domain decomposition is sufficient to justify an annual conference. It may be observed that the percentage of contributions advancing new theorems has gradually fallen from the earliest volumes, suggesting that available algebraic and function-theoretic foundations have largely been uncovered. (Perhaps there will be new graph-theoretic contributions, or infusions from other areas of mathematics in the future. In addition, we can expect relaxation of hypotheses to continue extending the theory to less ideal problems.) Meanwhile, the variety of algorithms and the variety of problems to which they are applied continue to grow, and the total number of contributions has been increasing dramatically. "Divide and conquer" may be the most basic of algorithmic paradigms, but theoreticians and practitioners alike are still seeking — and finding — incrementally more effective forms, and value the interdisciplinary forum provided by this proceedings series.

Besides inspiring elegant theory, domain decomposition methodology satisfies the architectural imperatives of high-performance computers better than methods operating only on the finest scale of the discretization (with no hierarchy) *and*, seemingly, better than methods operating simultaneously on all scales (with many levels of hierarchy). These imperatives include: spatial data locality, temporal data locality, reasonably small communication-to-computation ratios, and reasonably infrequent process synchronization (measured by the number of useful floating-point operations performed between synchronizations). Spatial data locality refers to the proximity of the addresses of successively used elements, and temporal data locality refers to the proximity in time of successive references to a given element. Spatial and temporal locality are both enhanced when a large computation based on nearest-neighbor updates is processed in contiguous blocks. On cache-based computers, subdomain blocks may be tuned for workingset sizes that reside in cache. On message-passing or cache-coherent nonuniform memory access (cc-NUMA) parallel computers, the concentration of gridpoint-oriented computations — proportional to subdomain volume — between external stencil edge-oriented communications — proportional to subdomain surface area, combined with a synchronization frequency of at most once per volume computation, gives domain decomposition excellent parallel scalability on a per iteration basis, provided only that the number of points per subdomain is not allowed to go below some problem-dependent and machine-dependent minimum in the scaling. In view of these important architectural advantages for domain decomposition methods, it is fortunate, indeed, that mathematicians studied the convergence behavior aspects of the subject in advance of the commercial arrival of these architectures, and showed how to endow domain decomposition iterative methods with some measure of algorithmic scalability, as well.

Domain decomposition has proved to be an ideal paradigm not only for execution on advanced architecture computers, but also for the development of reusable, portable software. Since the most complex operation in a Schwarz-type domain decomposition iterative method — the application of the preconditioner — is logically equivalent in each subdomain to a conventional preconditioner applied to the global domain, software developed for the global problem can readily be adapted to the local problem, instantly presenting lots of "legacy" scientific code for to be harvested for parallel implementations. Furthermore, since the only sharing of data between subdomains in domain decomposition codes occurs in two archetypal communication operations — ghost point updates in overlapping zones between neighboring subdomains, and global reduction operations, as in forming an inner product — domain decomposition methods map readily onto optimized, standardized message-passing environments, such as MPI.

Finally, it should be noted that domain decomposition is often a natural paradigm for the modeling community. Physical systems are often decomposed into two or more contiguous subdomains based on phenomenological considerations, such as the importance or neglibility of viscosity or reactivity, or any other feature, and the subdomains are discretized accordingly, as independent tasks. This physically-based domain decomposition may be mirrored in the software engineering of the corresponding code, and leads to threads of execution that operate on contiguous subdomain blocks, which can either be further subdivided or aggregated to fit the granularity of an available parallel computer, and have the correct topological and mathematical characteristics for scalability.

Organizing the contents of an interdisciplinary proceedings is an interesting job, and our decisions will inevitably surprise a few authors, though we hope without causing offense. It is increasingly artificial to assign papers to one of the four categories of theoretical foundations, algorithmic development, parallel implementation, and applications, that are traditional for this proceedings series. Readers are encouraged not to take the primary divisions very seriously, but to trace all the connections.

These proceedings will be of interest to mathematicians, computer scientists, and applications modelers, so we project its contents onto relevant classification schemes below.

American Mathematical Society (AMS) 1991 subject classifications include:

05C85 Graph algorihms

49J20 Optimal control

65C20 Numerical simulation, modeling

65D07 Spline approximation

65F10 Iterative methods for linear systems

65F15 Eigenproblems

65M55 Multigrid methods, domain decomposition for IVPs

65N30 Finite elements, Rayleigh-Ritz and Galerkin methods, finite methods

65N35 Spectral, collocation and related methods

65N55 Multigrid methods, domain decomposition for BVPs

65R20 Integral equations

65Y05 Parallel computation

68N99 Mathematical software

Association for Computing Machinery (ACM) 1998 subject classifications include:

D2 Programming environments, reusable libraries

E1 Distributed data structures

F2 Analysis and complexity of numerical algorithms

G1 Numerical linear algebra, optimization, differential equations

G4 Mathematical software, parallel implemenations, portability

J2 Applications in physical sciences and engineering

Applications for which domain decomposition methods have been specialized in this proceedings include:

fluids Stokes, Euler, Navier-Stokes, two-phase flow, reacting flow

geophysics porous media, atmospheric transport

manufacturing processes extrusion, free surface phenomena

physics neutron diffusion, semiconductor device physics

structures thermoelasticity, nonlinear elasticity, modal analysis

wave propagation acoustics, electromagnetics

For the convenience of readers coming recently into the subject of domain decomposition methods, a bibliography of previous proceedings is provided below, along with some major recent review articles and related special interest volumes. This list will inevitably be found embarrassingly incomplete. (No attempt has been made to supplement this list with the larger and closely related literature of multigrid and general iterative methods, except for the books by Hackbusch and Saad, which have significant domain decomposition components.)

1. T. F. Chan and T. P. Mathew, *Domain Decomposition Algorithms*, Acta Numerica, 1994, pp. 61-143.
2. T. F. Chan, R. Glowinski, J. Périaux and O. B. Widlund, eds., *Proc. Second Int. Symp. on Domain Decomposition Methods for Partial Differential Equations* (Los Angeles, 1988), SIAM, Philadelphia, 1989.
3. T. F. Chan, R. Glowinski, J. Périaux, O. B. Widlund, eds., *Proc. Third Int. Symp. on Domain Decomposition Methods for Partial Differential Equations* (Houston, 1989), SIAM, Philadelphia, 1990.
4. C. Farhat and F.-X. Roux, *Implicit Parallel Processing in Structural Mechanics*, Computational Mechanics Advances **2**, 1994, pp. 1–124.
5. R. Glowinski, G. H. Golub, G. A. Meurant and J. Périaux, eds., *Proc. First Int. Symp. on Domain Decomposition Methods for Partial Differential Equations* (Paris, 1987), SIAM, Philadelphia, 1988.
6. R. Glowinski, Yu. A. Kuznetsov, G. A. Meurant, J. Périaux and O. B. Widlund, eds., *Proc. Fourth Int. Symp. on Domain Decomposition Methods for Partial Differential Equations* (Moscow, 1990), SIAM, Philadelphia, 1991.

7. R. Glowinski, J. Périaux, Z.-C. Shi and O. B. Widlund, eds., *Eighth International Conference of Domain Decomposition Methods* (Beijing, 1995), Wiley, Strasbourg, 1997.
8. W. Hackbusch, *Iterative Methods for Large Sparse Linear Systems*, Springer, Heidelberg, 1993.
9. D. E. Keyes, T. F. Chan, G. A. Meurant, J. S. Scroggs and R. G. Voigt, *Proc. Fifth Int. Conf. on Domain Decomposition Methods for Partial Differential Equations* (Norfolk, 1991), SIAM, Philadelphia, 1992.
10. D. E. Keyes, Y. Saad and D. G. Truhlar, eds. *Domain-based Parallelism and Problem Decomposition Methods in Science and Engineering*, SIAM, Philadelphia, 1995.
11. D. E. Keyes and J. Xu, eds. *Proc. Seventh Int. Conf. on Domain Decomposition Methods for Partial Differential Equations* (PennState, 1993), MS, Providence, 1995.
12. P. Le Tallec, *Domain Decomposition Methods in Computational Mechanics*, Computational Mechanics Advances **2**, 1994, pp. 121–220.
13. A. Quarteroni, J. Périaux, Yu. A. Kuznetsov and O. B. Widlund, eds., *Proc. Sixth Int. Conf. on Domain Decomposition Methods in Science and Engineering* (Como, 1992), AMS, Providence, 1994.
14. Y. Saad, *Iterative Methods for Sparse Linear Systems* PWS, Boston, 1996.
15. B. F. Smith, P. E. Bjørstad and W. D. Gropp, *Domain Decomposition: Parallel Multilevel Algorithms for Elliptic Partial Differential Equations*, Cambridge Univ. Press, Cambridge, 1996.
16. J. Xu, *Iterative Methods by Space Decomposition and Subspace Correction*, SIAM Review **34**, 1991, pp. 581-613.

We also mention the homepage for domain decomposition on the World Wide Web, `www.ddm.org`, voluntarily maintained with professional skill by Tor Erling Bjørstad. This site features links to conference, bibliographic, and personal information pertaining to domain decomposition, internationally. In particular, there the reader will find a list with contact information to the authors of all 100 chapters of this book.

The technical direction of the Ninth International Conference on Domain Decomposition Methods in Scientific and Engineering Computing was provided by a scientific committee consisting of: Petter E. Bjørstad, James H. Bramble, Tony F. Chan, Peter J. Deuflhard, Roland Glowinski, David E. Keyes, Yuri A. Kuznetsov, Jacques Périaux, Alfio Quarteroni, Zhong-Ci Shi, Olof B. Widlund, and Jinchao Xu.

Local organization was undertaken by the following members of the faculty and staff at the University of Bergen: Petter E. Bjørstad, Merete Sofie Eikemo, Magne Espedal, Randi Moe, and Synnøve Palmstrøm.

The scientific and organizing committees, together with all attendees, are grateful to the following agencies, organizations, corporations, and departments for their financial and logistical support of the conference: The Norwegian Research Council, Statoil, Norsk Hydro, Sun Microsystems and Silicon Graphics.

It has turned out that the goals of traditional publishers (of proceedings) and the key objectives of the DDM proceedings as seen by the International Scientific Committee have become more and more orthogonal. We encourage broad participation and a complete proceeding showing the breath of contributions to the conference. The rapid growth of the Internet for dissemination of papers and the need to publish the proceedings in a more timely manner have led to the conclusion that the DDM proceedings shall be published directly by DDM.org starting with DD9 and DD11. (DD10 was published by AMS.) This is the first proceedings from the International Conference on Domain Decomposition Methods that is published in this way, by DDM.org, the established non-profit entity governed by the International Scientific Committee. The proceedings are freely available on the WEB page www.ddm.org as well as in book format. The editors are very grateful to Ole Arntzen and Jeremy Cook at the University of Bergen for their assistance with adapting the Latex macros to use in source-to-camera-ready preparation of the manuscript. Two distributed rounds of editing, with thanks to dozens of anonymous referees, and unforeseen technical difficulties, have delayed the release of these proceedings, but made them more worth the wait.

Our families graciously forsook much time together for this collection and are trusting, as are we, in a useful shelf life.

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