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This report lists all of the 39 scientific publications, theses, technical reports and conference presentations supported by the grant AFOSR 84-0385. The principal focus of the results are in 1) The Collocation Method: New versions developed for parallel machines, new results on the convergence and new software were developed, 2) Mapping Algorithms on to Parallel Machines. Fast heuristic algorithms were found, analyzed and tested, a prototype system for autmatically mapping PDE algorithms on to parallel architectures were developed.

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FINAL TECHNICAL REPORT

Parallel Algorithms for PDE Solvers
AFOSR Grant 84-0385
Period: October 1984 - February 1988

John R. Rice
July 15, 1988

This report covers activities of John R. Rice (PI) and associates. Kai Hwang was originally a co-PI, but moved to another university. His activities are not covered here. The principal activity is the publication of papers as follows:

Journal Articles:	15
Book Chapters:	3
Conference Proceedings Articles:	8
Ph.D. Theses:	2
Other Technical Reports:	11

In addition, technical presentations were made at 14 scientific conferences.

Many aspects have been studied of the relationship between parallelism and solution of partial differential equations. The two areas of focus and principal progress are *The Collocation Method.* We have developed new versions more suitable for parallel implementation, derived new theoretical and experimental results about its convergence, and created software for a variety of parallel architectures. *Mapping Algorithms on to Parallel Machines.* We have developed several fast heuristic algorithms for this, tested and evaluated them on a variety of algorithms and machines and have almost completed a prototype of a complete, automatic system to map PDE solving algorithms on to parallel architectures.

I. JOURNAL ARTICLES

[1] C.E. Houstis, E.N. Houstis and J.R. Rice, Partitioning PDE computations: methods and performance evaluation, *J. Parallel Comp.* **4** (1987), 141-163.

[2] W.R. Dyksen and C.J. Ribbens, Interactive ELLPACK: An interactive problem solving environment for elliptic partial differential equations, *ACM Trans. Math. Software*, **13** (1987), 113-132.

[3] E.N. Houstis, E.A. Vavalis and J.R. Rice, Convergence of $O(h^4)$ cubic spline collocation methods for elliptic partial differential equations, *SIAM J. Numer. Anal.*, **25** (1988), 54-74.

[4] D.C. Marinescu and J.R. Rice, Domain oriented analysis of PDE splitting algorithms, *J. Information Sciences*, **43** (1987), 3-24.

[5] E.N. Houstis, C.C. Christara and J.R. Rice, Quadratic spline collocation methods for two point boundary value problems, *Intl. J. Numer. Meth. Engr.*, **26** (1988), 935-952.

[6] W.R. Dysken, C.J. Ribbens and J.R. Rice, The performance of numerical methods for elliptic problems with mixed boundary conditions, *J. Numer. Sol. Part. Diff. Eqns.*, to appear.

[7] J. Bonomo and W.R. Dyksen, ADI methods on a shared memory machine, *J. Numer. Sol. Part. Diff. Eqns.*, to appear.

[8] E.N. Houstis and N.C. Charalanbakis, Analytical and numerical behavior of thermomechanical processes, *Engineering Analysis Journal*, to appear.

[9] M. Mu and J.R. Rice, An experimental performance analysis for the rate of convergence of collocation on general domains, *J. Numer. Sol. Part. Diff. Eqns.*, to appear.

II. ARTICLES SUBMITTED TO JOURNALS

[10] M. Irodotou-Ellina and E.N. Houstis, As $0(h^6)$ quintic spline collocation method for fourth order two-point boundary value problems.

[11] N.C. Charalanbakis and E.N. Houstis, Adiabatic shearing of incompressible non-Newtonian flows.

[12] C.J. Ribbens, An efficient method for constructing and applying adaptive grid domain mappings.

[13] C.J. Ribbens, A fast grid adaption scheme for elliptic partial differential equations.

[14] C.J. Ribbens, Efficient vector computation of adaptive grid domain mappings.

[15] C.J. Ribbens, Grid adaption for elliptic partial differential equations.

III. BOOK CHAPTERS

[16] J.R. Rice, Parallel methods for PDEs. Chapter 8 in *Characteristics of Parallel Algorithms* (Jamieson, Gannon and Donglass, ed.) (1987), 209-231.

[17] J.R. Rice, Mathematical aspects of scientific software. Chapter 1 in *Mathematical Aspects of Scientific Software*, IMA Volumes in Mathematics and its Applications, **14** (J. Rice, ed.), Springer-Verlag (1988), 1-39.

[18] E.N. Houstis, J.R. Rice, C.C. Christara and E.A. Vavalis, Performance of scientific software. Chapter 6 in *Mathematical Aspects of Scientific Software*, IMA Volumes in Mathematics and its Applications, **14** (J. Rice, ed.), Springer-Verlag (1988), 123-155.

IV. CONFERENCE PROCEEDINGS ARTICLES

[19] J.R. Rice, Parallelism in solving PDEs. *Fall Joint Computer Conf.* (1986), 540-546.

[20] J.R. Rice, Using supercomputers today and tomorrow. *Proc. Fourth Army Conf. Appl. Math. Comp.*, (1987), 1333-1343.

[21] C.J. Ribbens, A priori grid adaption strategies for elliptic PDEs. In *Advances in Computer Methods for Partial Differential Equations, VI* (R. Stepleman and Vichnevetsky, eds.), IMACS (1987), 102-107.

[22] C.E. Houstis, E.N. Houstis, J.R. Rice and M. Samartzis, Benchmarking of bus multiprocessor hardware on large scale scientific computing. In *Advances in Computer Methods for Partial Differential Equations, VI* (R. Stepleman and Vichnevetsky, eds.), IMACS (1987), 136-141.

[23] E.N. Houstis, J.R. Rice and E.A. Vavalis, Parallelization of a new class of cubic spline collocation methods. In *Advances in Computer Methods for Partial Differential Equations, VI* (R. Stepleman and Vichnevetsky, eds.), IMACS (1987), 167-174.

[24] D.C. Marinescu and J.R. Rice, Analysis and modeling of schwartz splitting algorithms for elliptic PDEs. In *Advances in Computer Methods for Partial Differential Equations, VI* (R. Stepleman and Vichnevetsky, eds.), IMACS (1987), 1-6.

[25] C.C. Christara, E.N. Houstis and J.R. Rice, A parallel spline collocation-capacitance method for elliptic partial differential equations. In *Supercomputing II*, Springer-Verlag (1988), to appear.

[26] E.N. Houstis, J.R. Rice and E.A. Vavalis, A schwartz splitting variant of cubic spline collocation methods for elliptic PDEs. In *Proc. Hypercubes 1988*, Academic Press (1988), to appear.

IV. PH.D. THESES

[27] Calvin J. Ribbens, Domain mappings: A tool for the development of vector algorithms for numerical solutions of partial differential equations, Purdue University, August 1986.

[28] Christina C. Christara, Parallel algorithms and architectures for the numerical solution of Partial Differential Equations, Purdue University, August 1988.

V. CONFERENCE PRESENTATIONS

All conference proceedings articles [19-26] were presented at scientific conferences. Article [20] was also presented at the conference *Supercomputers in Hydrology*, W. Lafayette, Indiana. September, 1986. In addition, the following papers were presented at conferences:

[1] Loen, Norway, June 1986

[7] SIAM National Meeting, July 1986

[16] SIAM National Meeting (invited address), July 1986

[37] Los Angles, Calif., December 1987

W.R. Dyksen, An expert system for elliptic PDEs. Invited address, First Internat. Conf. Appl. Math., Paris, June, 1986.

VI. TECHNICAL REPORTS

These reports are of two kinds, preliminary results or material not intended for formal publication. Reports directly related to papers cited earlier are omitted. Some of these reports represent work that might develop into future formal publications.

[29] J.R. Rice, Problems to test parallel and vector languages, CSD-TR 516, Computer Sciences Department, Purdue University (1985), 95 pages.

[30] J.R. Rice, Is the aspect ratio significant for finite element problems? CSD-TR 535, Computer Sciences Department, Purdue University (1985), 16 pages.

[31] C.E. Houstis, E.N. Houstis and J.R. Rice, Performance evaluation models for distributed computing, CSD-TR 576, Computer Sciences Department, Purdue University (1986), 19 pages.

[32] J.R. Rice, Multi-FLEX machines: preliminary report, CSD-TR 612, Computer Sciences Department, Purdue University (1986), 19 pages.

[33] J.R. Rice, Design of a tensor product population of PDE problems, CSD-TR 628, Computer Sciences Department, Purdue University (1986), 12 pages.

[34] C.J. Ribbens and J.R. Rice, Realistic PDE solutions for non-rectangular domains, CSD-TR 639, Computer Sciences Department, Purdue University (1986), 35 pages.

[35] H.S. McFaddin and J.R. Rice, Parallel and vector problems on the FLEX/32, CSD-TR 661, Computer Sciences Department, Purdue University (1987), 85 pages.

[36] H.S. McFaddin, E.N. Houstis and C.E. Houstis, On the mapping of parallel multigrid algorithms into parallel architectures, CSD-TR 699, Computer Sciences Department, Purdue University (1987), 26 pages.

[37] D.C. Marinescu and J.R. Rice, Nonhomogeneous parallel computations I: Synchronization analysis of parallel algorithms, CSD-TR 683, Computer Sciences Department, Purdue University (1987), 25 pages.

[38] M. Mu and J.R. Rice, An experimental performance analysis for the convergence of 5-point star on general domains, CSD-TR 747, Computer Sciences Department, Purdue University (1988), 31 pages.

[39] A. Hadjidimos, E.N. Houstis, J.R. Rice and E.A. Vavalis, Line cubic spline collocation methods for elliptic partial differential equations in multidimensions, CSD-TR 768, Computer Sciences Department, Purdue University (1988), 20 pages.

[40] C.E. Houstis, E.N. Houstis, J.R. Rice, D.L. Alexandrakis and S.M. Samartzis, Modeling and evaluation of parallel applications/architecture pairs using the "Algorithm Mapper", CSD-TR 800, Computer Sciences Department, Purdue University (1988).