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**ACTIVITIES AND OPERATIONS OF THE
ADVANCED COMPUTING RESEARCH FACILITY**

January 1989 through January 1990

Gail W. Pieper

Mathematics and Computer Science Division

February 1990

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ACTIVITIES AND OPERATIONS OF THE ADVANCED COMPUTING RESEARCH FACILITY: January 1989 through January 1990

by

Gail W. Pieper

Abstract

This report reviews the activities and operations of the Advanced Computing Research Facility (ACRF) for the period January 1, 1989, through January 31, 1990. The ACRF is operated by the Mathematics and Computer Science Division at Argonne National Laboratory. The facility's principal objective is to foster research in parallel computing. Toward this objective, the ACRF continues to operate experimental advanced computers and to sponsor new technology transfer efforts and new research projects.

1 Advanced Computing Research Facility: Highlights

The year 1989 marked the end of decade. For the Advanced Computing Research Facility (ACRF), however, it was less an end than a beginning—with new activities, new machines, and a new director. Among the new, we highlight the following:

- New scientific director, Ewing Lusk
- New machines, including the BBN TC-2000 (Butterfly II)
- New workshop/laboratory with a network of NeXT workstations
- New classes in Ada and Strand
- New industrial affiliates program coordinated by ARCH Development

In this 1989–90 annual report, we review these and other activities that have helped make the ACRF one of the world's leading centers for research in high-performance computing.

Undoubtedly our most widely publicized event during the past few months was the demonstration of the Japanese fifth-generation computer at the ACRF. This was the first demonstration of the machine, called the Multi-PSI, outside Japan. Japanese officials selected Argonne because of the leadership role of the ACRF in parallel computing and logic programming research.

Another notable event was the designation of the Australian National University (ANU) as our first international academic affiliate. E. Lusk, scientific director of the ACRF, has been actively

assisting ANU in establishing its new Parallel Computing Research Facility. Dr. M. McRobbie, the Executive Director of the Centre for Information Research at ANU, said that the experience gained with computers at the ACRF would be vital in helping to determine which machines would be acquired for the Australian research facility. The agreement also serves to strengthen the present research collaboration that exists between Argonne and the Australian National University in advanced computing and automated theorem proving.

All of these changes reflect the vitality of the ACRF at the start of a new decade. We intend to continue to select and operate computers with innovative designs that are likely to be effective for a wide range of scientific computing tasks. Equally important, we intend to continue our research in parallel programming, devising methodologies, studying automated reasoning, developing performance measurement techniques, and devising algorithms for supercomputer applications.

2 Expansion of the ACRF

2.1 New Machines

As part of our continuing efforts to have state-of-the-art machines available for experimentation, we temporarily had available a Stellar Computer Graphics Workstation. This machine allowed users to view in real time an animation of some computational problems. Such capabilities are becoming increasingly important for large-scale scientific computing.

We have also added to the ACRF two new machines:

The **BBN Butterfly TC-2000** (a.k.a. Butterfly II) is a 45-node, shared-memory parallel computer. It is built around one of the fastest available microprocessors, the Motorola 88000, and it represents a new model of computation, called NUMA (Non-uniform Memory Access). The machine provides a single address space, like a shared-memory multiprocessor, yet is programmed to perform efficiently only when locality of data is taken into account. Such architectures are necessary in order to provide a shared-memory programming environment with more than about twenty-five processors.

The machine was obtained as a combined purchase with Michigan State University (MSU), which acquired a 96-node **BBN Butterfly GP-1000**. High-speed computer network connections between MSU and Argonne have been installed to enable researchers to conduct experiments on both BBN parallel computers. The cooperative arrangement was made possible by the BBN Advanced Computers Science Office and was funded in part by the National Science Foundation Science and Technology Center for Research in Parallel Computation.

The ACRF also features eight other advanced computers:

- Active Memory Technology DAP 510, with 1024 processors arranged in a 32 by 32 array, with a total of 8 megabytes of memory.
- Alliant FX/8, with 8 vector processors sharing 32 megabytes of memory.
- Ardent Titan, with 4 processors and a peak performance of 64 Mflops.
- Connection Machine Model 2, manufactured by Thinking Machines, with 16,384 one-bit processors each having 8 kilobytes of memory.

2.2 New Workstation Laboratory

The Mathematics and Computer Science (MCS) Division established a new workstation laboratory to be used for teaching the ACRF courses and other advanced courses on object-oriented programming and computer algebra. The laboratory comprises a network of 11 NeXT computers, connected to each other and to the ACRF parallel machines and graphics workstations. The NeXT computers offer advanced software development environment, the Mach operating system, and Display Postscript Imaging models. We are also experimenting with Mathematica and the Objective-C programming environment.

2.3 New File Server

To provide large amounts of online storage economically, the ACRF installed a 29-gigabyte Epoch-1 fileserver. The Epoch-1 combines cache memory, magnetic disks, and optical disks in an integrated storage system for our networked workstations. The system is used primarily by the heaviest users of computing in the ACRF—researchers with massive data files of genetic sequences, for example. The data is online and readily available, but does not tie up the Sun servers. The Epoch-1 fileserver is part of a cooperative project with Epoch systems to determine the suitability of such servers for advanced scientific computing environments.

2.4 New Director

In January 1990, Ewing Lusk was named Scientific Director of the ACRF. Since the establishment of the ACRF in 1984, Lusk has played an important role in overseeing research in parallel programming. He was Deputy Scientific Director of the ACRF from 1984 to 1989, and served as Acting Scientific Director from September to December 1989. A senior scientist in the MCS Division, Lusk's current research interests lie in logic programming and parallel programming methodologies. He has played a major role in the Gigalips Project to develop an Or-parallel Prolog system, has designed a parallel monitor-macros technique for advanced-computer architectures, and is co-author of the book *Portable Programs for Parallel Processing*.

2.5 New Center

In December 1988, the National Science Foundation awarded the Science and Technology Center for Research in Parallel Computation to a consortium of researchers at Rice University, Caltech, Los Alamos, and Argonne. Argonne's role is twofold: we are providing Center members with access to a variety of advanced computers, and we are conducting research in composition systems using techniques in bilingual programming. Members of the MCS Division serve on the Technical Committee, the Facilities Committee, and the Executive Committee to help guide the Center in its study and development of efficient programming methods for state-of-the-art parallel computers.

3 Research

Since its establishment in 1984, the ACRF has encouraged research in algorithm design, parallel programming languages, and new techniques and tools to make parallel computing easier and more efficient. Here we highlight recent successes of our scientific staff in the Mathematics and Computer Science Division.

3.1 Algorithm Design

Steve Wright developed a partitioned Gaussian elimination algorithm with partial pivoting which is suitable for multiprocessors with small to moderate numbers of processing elements. The linear system is assumed to be non-singular; hence, the submatrices in the chosen partitioning may be rank-deficient, making the algorithm more complex than those proposed for diagonal-dominant and symmetric-positive definite systems. The algorithm has been implemented and tested on the Alliant FX/8, Sequent Balance, and Encore Multimax. Wright has also developed several locally convergent algorithms for discrete-time optimal control problems which are amenable to multiprocessor implementation. Parallelism is achieved both through concurrent evaluation of the component functions and their derivatives and through the use of a parallel band solver which solves a linear system to find the steps at each iteration.

Fig. 2: Partition ℓ after phase 2 of the algorithm

Chris Bischof developed a new algorithm for computing the QR factorization of a rank-deficient matrix on high-performance machines. The algorithm is based on the Householder QR factorization algorithm with column pivoting. The traditional pivoting strategy is not well suited for machines with a memory hierarchy, since it precludes the use of matrix-matrix operations. Bischof therefore introduced a restricted pivoting strategy that allows one to formulate a block QR factorization algorithm where the bulk of the work is in matrix-matrix operations. Implementation results on the CRAY-2, CRAY X-MP, and CRAY Y-MP show that the new algorithm performs significantly better than the traditional scheme and can more than halve the cost of computing the QR factorization.

Marc Garbey and *David Levine* formulated a new method computing solutions of conservation laws that is based on the method of characteristics and exploits the high degree of parallelism available with cellular automata. Garbey and Levine have implemented the method for a Dirichlet problem with a single conservation law for the one-dimensional case. The method yields high numerical accuracy and extends naturally to adaptive meshes and domain decomposition methods for perturbed conservation laws. The algorithm is well suited for both massively parallel computers and vector computers. The researchers are currently extending the method to two dimensions, using a cylindrical cell with hexagonal basis.

Fig. 3: Domain decomposition

3.2 Tools for Parallel Programs

L. Bomans and *R. Hempel* have defined and implemented a macro package for portable parallel programming on parallel computers with local memory. The package is based on Argonne's monitor-macros package originally developed for machines with shared memory. The new macros, written in Fortran, have been tested on the Encore Multimax, the Sequent Balance, the Alliant FX/8, the Intel hypercubes, and a network of Sun workstations. Considerable effort has been expended on performance optimization, with the result that it is possible to use the portable macros as efficiently as machine-dependent function calls.

Orlie Brewer, Jack Dongarra, and Danny Sorensen developed a graphics tool called BUILD that can be used to help automate the process of writing parallel Fortran programs for the SCHEDULE package. The user can interactively build an execution graph that describes an algorithm and then have the tool generate the necessary calls to the SCHEDULE package.

Fig. 4: Execution graph of the triangular solve

3.3 Performance Evaluation

Rick Stevens and *Peter McDonough* are investigating various methods of collecting low-level C/Paris instruction execution times for the Connection Machine. They have written an adaptive timing code to collect actual execution times for single instructions and code fragments. This adaptive scheme reduces the runtime needed to collect the benchmark data without loss of accuracy. The results can be used for optimizing CM-2 programs and understanding choices during implementation of C/Paris programs.

Nick Karonis has formulated a new timing methodology capable of accurately determining the execution time of parallel programs. Conventional techniques for accumulating timing data for sequential programs are not powerful enough to solve the special problems introduced by parallelism. Karonis's timing methodology not only makes it possible to compare relative speedups and scalability of parallel algorithms, but it also is capable of acquiring timing data when the number of processes exceeds the number of physical CPUs. Through simulation, this methodology also provides a means for studying the behavior of a parallel program under an arbitrary hardware/software communications configuration.

3.4 Schemes for Efficient Parallelization

Anita Jindal, Ross Overbeck and Waldo Kabat developed a scheme for parallelizing first-order logic deduction systems. The scheme has been successfully used for parallelizing OTTER, a powerful reasoning system developed at Argonne. The new parallel deduction system, called PARROT-II) has attained real speedups in excess of 20 over the best results of current sequential deduction systems. These results are of especial interest because this is the first case in which a system has successfully exploited parallelism to outperform the best sequential deduction systems on difficult problems. Moreover, the approach can be generalized to other deduction paradigms.

Fig. 5: Process configuration of PARROT-II on two Sequent Symmetry machines

Ambuj Singh and *Ross Overbeek* developed an algorithm in Unity (a formalism developed by Chandra and Misra) and produced an efficient implementation in C. Singh and Overbeek Using an example from genetic sequence analysis, Singh and Overbeek demonstrated the benefits of using a formal design method. Specifically, they implemented abstract data types, then assigned statements onto processes, and finally addressed synchronization issues. The derived program was then translated to a real programming language on the target machine. A distinct advantage of the formal method is that refinements for different architectures share much of the initial development.

Fig. 6: Process network for 3 sets and 2 bins

Terry Harmer and *James Boyle* have also addressed the question of increasing parallelism. They have used program transformations that are applied automatically to transform clear, function program specifications (written in pure Lisp) into efficient parallel Fortran or C code. For practical applications in integer programming and graph theory, the transformations derive programs whose execution speeds are comparable to handwritten and carefully tuned parallel Fortran implementations.

Fig. 7: One-processor case

3.5 Parallel Programming Languages

Multiprocessor architectures imply a need for tools that provide portability across wide classes of parallel architecture. The state of the art in the development of such tools is not very advanced. Parallel extensions to existing sequential languages such as Fortran or C have been used on shared-memory architectures, but these do not provide portable programs. *Ian Foster* and *Steve Taylor* have been involved in the development of a more practical parallel programming tool called Strand. Strand is a high-level programming language derived from logic programming. Unlike languages such as Prolog, however, it permits the programmer to explicitly program parallel languages. Strand has been implemented efficiently on a broad range of multiprocessor architectures and has been used to develop applications in circuit verification, compiler implementation, and design of a high-performance theorem prover.

Foster and his colleagues are currently using Strand in an Argonne project to develop tools for DNA sequencing. Strand is used to express top-level program logic; C is used to implement computationally intensive kernels. The *bilingual programming* style permits rapid prototyping of algorithms without compromising performance.

Taylor and Foster have also collaborated with C. Kesselman (Aerospace Corp.) to produce a parallel performance monitoring tool for Strand. The tool, called Gauge, allows a wide variety of data to be gathered about the parallel execution of programs written in Strand and other languages. Researchers are using these data to improve the performance of bilingual programs.

Fig. 8: Example profile from Gauge

4 Publications, Preprints, and Presentations

One important measure of the success of our work is the publication of papers and the presentation of our results to the scientific community. Listed below are publications, preprints, and presentations relating to advanced computing research during the past year. This list updates the lists given in previous progress reports [1,2,3,4].

Books

I. Foster, *Systems Programming in Parallel Logic Languages*, Prentice-Hall, Englewood Cliffs, 1990

I. Foster and S. Taylor, *Strand: New Concepts in Parallel Programming*, Prentice-Hall, Englewood Cliffs, 1989

E. L. Lusk and R. A. Overbeek, eds., *Logic Programming*, The MIT Press, Cambridge, Mass., 1989

Publications in Books and Refereed Journals

C. H. Bischof, "Adaptive Blocking in the QR Factorization," *The Journal of Supercomputing* 3 (1989) 193-208 (also MCS-P39-1288)

C. H. Bischof, "Computing the Singular Value Decomposition on a Distributed System of Vector Processors," *Parallel Computing* 11 (1989) 171-186 (also MCS-P71-0389)

C. H. Bischof, "A Pipelined QR Factorization Algorithm with Adaptive Blocking," *Vector and Parallel Computing Issues in Applied Research and Development*, ed. J. Dongarra, I. Duff, P. Gaffney, and S. McKee, Ellis Horwood Publishers, Chichester, U.K., 1989, pp. 10-20

C. H. Bischof and J. J. Dongarra, "A Project for Developing a Linear Algebra Library for High-Performance Computers," *Parallel and Vector Supercomputing: Methods and Algorithms*, ed. G. Carey, John Wiley & Sons, Somerset, N.J., 1989, pp. 45-56 (also MCS-P105-0989)

R. Butler, T. Butler, I. Foster, N. Karonis, R. Olson, N. Pfluger, M. Price, and S. Tuecke, "Aligning Genetic Sequences," *Strand: New Concepts in Parallel Programming*, ed. I. Foster and S. Taylor, Prentice-Hall, Englewood Cliffs, 1989, pp. 253-271 (slightly modified version of MCS-TM-132, June 1989)

W. R. Cowell, "DO Loop Transforming Tools," *Using Toolpack Software Tools*, ed. A. Pollicini, Kluwer, Boston, 1989, pp. 161-180

W. R. Cowell, "Tool Writing," *Using Toolpack Software Tools*, ed. A. Pollicini, Kluwer, Boston, 1989, pp. 251-275

W. R. Cowell and C. P. Thompson, "Tools to Aid in Discovering Parallelism and Localizing Arithmetic in Fortran Programs," *Software Practice and Experience* 20 (1990) 25-47 (also MCS-P6-1088)

J. J. Dongarra, D. C. Sorensen, and S. J. Hammarling, "Block Reduction of Matrices to Condensed Forms for Eigenvalue Computations," *J. Comp. and Appl. Math.* 27 (1989) 215-227

J. Scroggs and D. Sorensen, "An Asymptotic Induced Numerical Method for the Convection-Diffusion-Reaction Equation," *Mathematics for Large Scale Computing*, ed. J. C. Diaz, Marcel Dekker, Inc., New York, 1989, pp. 81-113 (also MCS-P92-0789)

Contributions to Conference Proceedings

C. H. Bischof, "A Block QR Factorization Algorithm Using Restricted Pivoting," Proceedings SUPERCOMPUTING '89, ACM Press, Baltimore, 1989, pp. 248-256 (also MCS-P94-0789)

O. Brewer, J. Dongarra, D. Levine, and D. Sorensen, "Graphics Tools for Developing High-Performance Algorithms," Parallel Computing: Methods, Algorithms and Applications, 1989, pp. 39-50 (also MCS-P28-1288)

O. Brewer, J. Dongarra, and D. Sorensen, "A Graphics Tool to Aid in the Generation of Parallel Fortran Programs," Proc. 13th Annual International Computer Software & Applications Conf., IEEE, Washington, 1989, pp. 89-93 (also MCS-P68-0389)

I. Foster and S. Taylor, "Strand: A Practical Parallel Programming Tool," Logic Programming, ed. E. L. Lusk and R. A. Overbeek, The MIT Press, Cambridge, Mass., 1989, pp. 497-512 (also MCS-P80-0689)

Preprints

C. H. Bischof, "Incremental Condition Estimation," MCS-P15-1088 (SIAM J. on Matrix Analysis and Applications, to appear)

C. H. Bischof, "A Parallel QR Factorization Algorithm with Controlled Local Pivoting," MCS-P21-1088 (SIAM Journal on Scientific and Statistical Computing, to appear)

C. H. Bischof and P. C. Hansen, "Structure-Preserving and Rank-Revealing QR-Factorizations," MCS-P100-0989

C. H. Bischof, D. J. Pierce, and J. G. Lewis, "Incremental Condition Estimation for General Matrices," MCS-P106-1189

C. H. Bischof and G. M. Shroff, "On Updating Signal Subspaces," MCS-P101-0989

L. Bomans and R. Hempel, "The Argonne/GMD Macros in FORTRAN for Portable Parallel Programming and Their Implementation on the Intel iPSC/2," MCS-P98-0889

J. Dongarra, O. Brewer, S. Fineberg, and J. A. Kohl, "A Tool to Aid in the Design, Implementation, and Understanding of Matrix Algorithms for Parallel Processors," MCS-P115-1189

I. Foster, "A Multicomputer Garbage Collector for a Single-Assignment Language," MCS-P81-0689 (International J. of Parallel Programming 18, no. 3, to appear)

I. Foster and R. Stevens, "Parallel Programming with Algorithmic Skeletons," MCS-P124-0190

M. Garbey and D. Levine, "Massively Parallel Computation of Conservation Laws," MCS-P85-0689

T. Harmer and J. M. Boyle, "An Optimization to Increase Parallelism in Parallel Pure Lisp Implementations," MCS-P88-0689

A. Jindal, R. Overbeek, and W. C. Kabat, "Exploitation of Parallel Processing for Implementing High-Performance Deduction Systems," MCS-P121-0190

N. T. Karonis, "Timing Parallel Programs That Use Message Passing," MCS-P119-0190

E. Lusk et al., "The Aurora Or-Parallel Prolog System," MCS-P122-0190

A. K. Singh and R. Overbeek, "Derivations of Efficient Parallel Programs: An Example from Genetic Sequence Analysis," MCS-P104-0989

J. K. Slaney and E. L. Lusk, "Parallelizing the Closure Computation in Automated Deduction," MCS-P123-0190

R. L. Stevens, "The Interesting Future of Supercomputing," MCS-P110-1189

R. Stevens and P. McDonough, "Instruction Timings and Message Passing Performance of the Connection Machine 2," MCS-P76-0489

S. J. Wright, "A Parallel Algorithm for Banded Linear Systems," MCS-P64-0289

S. J. Wright, "Solution of Discrete-Time Optimal Control Problems on Parallel Computers," MCS-P89-0789

Technical Reports

M. Carlsson, K. Danforth, and R. Overbeek, "Practical Issues Relating to the Internal Database Predicates in an OR-Parallel Prolog: Extensions and Useful Hacks," ANL-88-11 (February 1988)

J. Dongarra and E. Lusk, "Summer Institute in Parallel Computing: September 5-15, 1989," MCS-TM-136 (January 1990)

A. Jindal, R. Overbeek, and W. McCune, "A Parallel Processing Approach for Implementing High-Performance First-Order Logic Deduction Systems," MCS-TM-131 (April 1989)

Oral Presentations

E. Anderson, "LAPACK Preliminary Benchmark Results," Numerical Algorithms Group, Ltd., England, April 18, 1989

C. H. Bischof, "A Parallel QR Factorization Algorithm Using Local Pivoting," 4th Conf. on Hypertubes, Concurrent Computers, and Applications, Monterey, California, March 6-8, 1989

C. H. Bischof, "Incremental Condition Estimation and Applications," 3rd SIAM Conf. on Optimization, Boston, April 3-5, 1989

C. H. Bischof, "A Rank-Identifying QR Factorization Algorithm for a Distributed-Memory Multiprocessor," 4th International Conf. on Supercomputing, San Jose, May 3, 1989

C. H. Bischof, "Parallel Algorithms for Eigenvalues and Least Squares Problems," XOX Corp., Minneapolis, July 7, 1989

C. H. Bischof, "Incremental Condition Estimation and Applications," 1989 SIAM National Meeting, San Diego, July 17-21, 1989

C. H. Bischof, "Algorithms for Solving Sparse Rank-deficient Linear Least Squares Problems," Center for Research and Advanced Training in Scientific Computation, Toulouse, France, October 2-3, 1989

C. H. Bischof, "Computing a Rank-Identifying QR Factorization on a Distributed-Memory Multiprocessor," European Workshop on Hypercube and Distributed Computers, Rennes, France, October 4-6, 1989

C. H. Bischof, "Solving Rank-Deficient Least-Squares Problems on High-Performance Architectures," KFA, Julich, West Germany, October 9, 1989

C. H. Bischof, "Inexpensive and Reliable Rank Identification for Structured Matrices," Konrad-Zuse Zentrum, Berlin, October 10, 1989

C. H. Bischof, "Designing Efficient Algorithms for Computing Orthogonal Decompositions and Modeling Linear Algebra Kernels," Gesellschaft fur Mathematik und Datenverarbeitung, Bonn, West Germany, October 18, 1989

C. H. Bischof, "Recent Work on Orthogonal Factorizations of Sparse Matrices," RPI, Troy, October 29-30, 1989

C. H. Bischof, "A Block QR Factorization Algorithm Using Restricted Pivoting," SIAM Conf. on Parallel Processing and Scientific Computing, Chicago, December 6-8, 1989

J. Boyle, "Programming Models, Program Transformation, and Efficient Parallel Programming," RISC Institute, Linz, Austria, April 23-25, 1989

O. Brewer, J. Dongarra, and D. Sorensen, "A Graphics Tool to Aid in the Generation of Parallel FORTRAN Programs," Thirteenth Annual International Computer Software & Applications Conference, Orlando, FL, September 21, 1989

J. J. Dongarra, "SCHEDULE: An Aid to Programming Explicitly Parallel Algorithms in Fortran," SIAM Annual Meeting, San Diego, July 17-21, 1989

K. Dritz, "Parallel Programming in Ada," Strategic Defense Command, Huntsville, Alabama, June 26-30, 1989

M. Ewerbring, "HK Singular Value Decomposition," Great Lakes Computer Science Conf., Western Michigan University, Kalamazoo, October 17, 1989

M. Ewerbring, "Matrix Computing on the Connection Machine," Stockholm, Sweden, November 27-28, 1989

M. Ewerbring, "Singular Value Computations on Massively Parallel Machines," IEEE TENCON Conf., Bombay, India, November 20-21, 1989

D. Levine, "Recent work with the Argonne Monitor/Macro Send/Recv Packages," poster session, Supercomputing '89, November 14-17, 1989

D. Levine, "Massively Parallel Computation of Conservation Laws," Supercomputing '89, November 14-17, 1989

D. Levine, "Recent work with the Argonne Monitor/Macro Send/Recv Packages," poster session, SIAM Conf. on Parallel Processing and Scientific Computing, Chicago, December 6-8, 1989

D. Levine, "Massively parallel computation of conservation laws," SIAM Conf. on Parallel Processing and Scientific Computing, Chicago, December 6-8, 1989

D. Levine, "The ACRF and Massively Parallel Computation of Conservation Laws," seminar, Supercomputing Research Institute, Florida State University, Tallahassee, November 18-19, 1989

D. Sorensen, invited lecture, 1989 SIAM National Meeting, San Diego, July 17, 1989

D. Sorensen, "Recent Improvements to the SCHEDULE Package," NATO Advanced Workshop on Supercomputing, Trondheim, Norway, June 19-23, 1989

R. Stevens, "Instruction Timings and Message Passing Performance of the Connection Machine 2," 4th Conf. on Hypercubes, Concurrent Computers, and Applications, Monterey, California,

March 6-8, 1989

R. Stevens, "Advanced Scientific Computing," AESOP Operations Managers Conf., Morgantown, West Virginia, June 7-9, 1989

R. Stevens, "The Interesting Future of Supercomputing," Computer and Geophysical Research Conf., Houston Area Research Center, Houston, Texas, April 24-26, 1989

Books and Other Papers Citing Argonne's ACRF

L. Bachrach, "Parallel Algorithms for the Finite Element Method," J. Mechanics Research Communications, 16, no. 1 (1989) 3-18

J. Barlow and U. Vemulapati, "An Improved Method for One-Way Dissection with Singular Diagonal Blocks," Technical Report CS-89-05, The Pennsylvania State University, University Park, PA, February, 1989

R. B. Mattingly and C. D. Meyer, "Computing the Stationary Distribution Vector of an Irreducible Markov Chain on the Shared-Memory Multiprocessor," 1st International Workshop on the Numerical Solution of Markov Chains, Raleigh, NC, January 8-10, 1990

E. N. May, "Portable Parallel Programming in a Fortran Environment," '89 Conference on Computing in High Energy Physics, New College, Oxford, England, April, 1989

L. Mukkavilli and G. M. Prabhu, "Divide-and-Conquer Algorithms for Multiprocessors," presented at the Fourth Hypercube Conference, Monterey, California, early 1989

R. B. Mueller-Thuns, D. G. Saab, R. F. Damiano, and J. A. Abraham, "Portable Parallel Logic and Fault Simulation," Proceedings of the International Conference on Computer Aided Design (ICCAD-89), Santa Clara, CA, November 1989

N. Nayar and G. M. Prabhu, "Implementing Graph Algorithms on Multiprocessors," presented at the Fourth Hypercube Conference, Monterey, California, early 1989 D. A. Ratner, (lqThe Parallel Iterative Solution of Large Linear Systems,(rq technical report required for master's degree, University of Kansas, 1989

F. L. Tabel, "Simulation of Parallel Neuron-Like Circuits," AIL Systems, Inc., Melville, NY, November 6, 1989

V. M. Umar and C. F. Fischer, "Multitasking the Davidson Algorithm for the Large Sparse Eigenvalue Problem," Technical Report CS-89-05, Vanderbilt University, Nashville, TN, January 1989

A. C. Yu and B. W. Wah, "Design and Evaluation of a Pre-Compiler for Multiprocessing of Lisp Programs," Proceedings of Triennial Congress on Cybernetics and Systems, June 1990

5 The ACRF—A User Facility

The ACRF was established to be used for advanced computing research by researchers throughout the world. To encourage use of the ACRF's specialized resources, the Mathematics and Computer

Science Division conducts classes; supports an active visitors program; and sponsors a variety of seminars, workshops, and institutes.

5.1 Classes

Argonne conducted bimonthly classes on parallel computing during the past year. The attendees, averaging 20-25 persons per class, represented universities, industry, and various research laboratories throughout the country. The classes familiarize the attendees with the ACRF environment, offer ample hands-on experience on the parallel computer systems, and help the attendees apply parallel programming to their particular area of research. Session topics include parallel compilers; monitors and their implementation with macros; the SCHEDULE package; and special techniques for programming the various architectures.

Two new classes were added this year.

- In response to requests from the Strategic Defense Initiative community, K. Dritz developed an Ada version of the parallel programming class. Here the focus is on the language rather than methodology for writing portable programs, since features supporting concurrency are built into the Ada language. Dritz has also modified the class into a tutorial/workshop, in which he introduces researchers to the fundamental concepts of concurrency and the Ada features for tasking.
- Ian Foster and Rick Stevens offered a one-day tutorial on parallel programming in Strand on November 13, 1989. The tutorial began with basic concepts and fundamental programming techniques, and then covered a number of case studies. In each case, a problem was described, a parallel algorithm developed, and the implementation of the algorithm considered. The Strand class was the first to be taught in the new ACRF classroom/laboratory on the NeXT machines.

5.2 Proposals

One of the objectives of the ACRF classes is to encourage researchers to use our advanced computers. Frequently, after attending a class, researchers wish to continue using the ACRF machines. During 1989, approximately 315 projects were proposed and approved by the ACRF staff.

5.3 College and University Courses

In addition to the classes offered by the ACRF staff, several colleges and universities used the ACRF machines for courses in advanced computing. In particular, we note the following:

- Andrews University, Berrien Springs, Michigan - "Selected Topics in Parallel Computing"
- Florida Institute of Technology - "Parallel Numerical Algorithms"
- University of Illinois, Chicago - "Introduction to Supercomputing"
- University of Missouri - Rolla - "Development and Implementation of Parallel Algorithms"
- Youngstown State University - "Vector and Parallel Solutions to Linear Systems"

In addition, the University of Illinois at Chicago sponsored a quarterly Workshop Program on Scientific Computing, in which students spent time optimizing applications for parallelization and vectorization on advanced computers. Other colleges using the ACRF machines for student instruction include Elmhurst College (for symbolic manipulation investigations) and Kent State University (for studying the Traveling Salesman problem on SIMD machines, e.g.).

5.4 Faculty Internship

Under a Faculty Internship funded by the National Science Foundation, Stephen Wright (North Carolina State University) spent almost a year at Argonne developing algorithms for advanced-computer architectures, both vector and parallel.

Among his achievements was the development of an algorithm for solving general banded linear systems on multiprocessors. Unlike existing methods, this one can—in principle—produce a solution to any nonsingular system. A nested dissection strategy is used to partition the matrix into main diagonal blocks which are factorized separately, leading to a smaller, "reduced" system that can be solved on one processor. The method takes account of the possibility that rank deficiency may occur in the submatrices. When this occurs, the size of the reduced system may be increased slightly, but a solution can still be obtained. The algorithm has been implemented on the ACRF's Alliant, Sequent, and Encore multiprocessors with the aid of the SCHEDULE parallel programming package.

In a related area, Wright studied the solution of the nearly block-diagonal linear systems that arise from the finite difference discretization of two-point boundary value problems. The methods he and his colleagues developed are most suited to computers with vector-processing capabilities, such as the Cray machines. In contrast to existing methods, the computations are arranged so that the length of the vectors is equal to the order of the chosen discretization, rather than the order of the underlying differential equation (which is usually smaller). The methods have application to algorithms for seismic ray-tracing, which in turn are used in earthquake location and seismic prospecting.

5.5 Visitors

During the past year, we have had numerous visitors here working on projects involving computer graphics, high-performance algorithms, and software tools for advanced-architecture computers: These visitors, who include scientists from industry and academia, stay for periods ranging from two weeks to several months.

Faculty and Senior Visitors

Moody Chu, Faculty Research Leave at Argonne
North Carolina State University

Parallel processing of ordinary differential equations

James Northrup, Faculty Participant
North Carolina State University

Parallelization of algorithms on shared-memory multiprocessors

Terence J. Harmer, Assistant Scientist
Queen's College, Belfast

Parallelizing SDI BM/C3 algorithms, using abstract programming

Marc Garbey, Research Associate
Ecole Normale Supérieure de Lyon

Domain decomposition studies on the Alliant and Butterfly II

Stephen Wright, Research Associate
North Carolina State University

Vectorized solutions of linear systems on the CRAY and Alliant

Sven Hammarling, Visiting Scholar
NAG, Inc.

Efficient implementation of block algorithms on the Cray

Axel Ruhe, Visiting Scholar
Gothenburg University

Visualization of perturbations of matrix eigenvalues on the Ardent

Students and Other Visitors

Orlie Brewer, Scientific Assistant
Argonne National Laboratory

Graphics tool for displaying the memory access patterns of arrays in Fortran programs

Samuel A. Fineberg, Scientific Assistant
Purdue University

Converting parallel graphics tools to run under X Windows

Andrea Hudson, Scientific Assistant
University of Kentucky

Code development for the Connection Machine and Sequent

Nicholas T. Karonis, Scientific Assistant
Syracuse University

Development of SIMD algorithms on the Connection Machine

James A. Kohl, Scientific Assistant
Purdue University

Animated tool that allows visualization of events in a parallel system

Edward Anderson, Scientific Associate
University of Illinois, Urbana

Writing and testing software for LAPACK

Anita Jindal, Resident Student Associate
University of Illinois, Chicago

New scheme for parallelizing propositional theorem provers

David Joerg, Pre-College Program
Illinois Math and Science Academy

Development of a decomposition scheme for a weather model, using bilingual programming

Virginia Herrarte, Student Research Program
Blackburn College

Graphics tools for studying the behavior of parallel programs

Thomas A. Homulka, Student Research Program
Northwestern University

Development of code based on domain decomposition techniques for the CRAY

Ramona Lingeitch, Student Research Program
Blackburn College

Performance monitoring tools to graphically display parallel programs

Frank E. Spivey, Student Research Program
Chicago State University

Instruction timings and message passing on the Connection Machine

5.6 Japanese Demonstration of the Multi-PSI

Japanese computer designers presented the latest experimental prototype of their fifth-generation computer at Argonne National Laboratory on Oct. 11-13, 1989. This is the first time that the machine has been demonstrated outside Japan. Japanese officials selected Argonne because of the leadership role of the ACRF in parallel computing research. The occasion for the demonstration was a joint Japanese-American Workshop on Logic Programming and Parallel Computing, sponsored jointly by the National Science Foundation and the Japanese Institute for New Generation Computer Technology (ICOT).

Part of the workshop was devoted to examining and evaluating ICOT's new computer system. This system, called the Multi-PSI, combines capabilities for advanced symbolic computation and parallel processing. The model demonstrated at the ACRF featured 16 processors; a larger version in Japan has 64 parallel processors. The goal is to have a 1000-processor system available for marketing by 1992.

The Japanese demonstrated a variety of parallel application programs on the Multi-PSI, including a pentomino packing piece puzzle and a natural language parser. Both programs used new load-balancing methods, with mixed success: the pentomino puzzle achieved almost linear speedup

on 16 processors, but the parsing program was considerably slower. One of the most promising demonstrations involved a new database management system called Kappa. ICOT has stored on Kappa more than 7000 entries from GenBank's sequences of invertebrates, viruses, bacteria, and phages. Researchers from Argonne plan to meet with the Japanese in early 1990 to discuss potential collaborations in molecular biology.

5.7 Seminars

During 1989, the MCS Division sponsored a series of seminars on high-performance computing. Below are listed the names of our speakers, their affiliations, and the title of their talk.

Robert Schreiber, *Large Compiling for a Memory Hierarchy*, NASA Ames Research Center, January 23, 1989

Tim Peierls, *Sparse Partial Pivoting on a Multiprocessor*, AT&T Bell Laboratories, February 10, 1989

David Gelernter, *Parallelism to the People*, Yale University, February 16, 1989

Per Christian Hansen, *Solution of Discrete Regularization Problems by Means of Truncated SVD*, Technical University of Denmark, March 14, 1989

Mark Davoren, *Parallel Computing in Edinburgh and the U.K.*, University of Edinburgh, March 22, 1989

Eric Van de Velde, *Multicomputer Matrix Computations: Theory and Practice*, Caltech, March 30, 1989

Zahari Zlatev, *A Sparse Matrix Code for the Alliant FX/9 and CEDAR*, Center for Supercomputing Research and Development, April 13, 1989

Pierre Leca, *Parallel Computing Activities at ONERA, France*, Parallel Computing Division, ONERA, France, April 25, 1989

John L. Hennessy, *A Scalable, Shared-Memory Multiprocessor Architecture*, Stanford University, May 2, 1989

George Cybenko, *Hyperbolic Householder Based Algorithms for Toeplitz and Close-to-Toeplitz Matrices*, Center for Supercomputing Research and Development, Univ. of Illinois, May 11, 1989

Alan Norton, *Computer Animation at IBM Research*, IBM T. J. Watson Research Center, May 18, 1989

M. Arioli, *On the Augmented System Approach to Sparse Least-Squares Problems*, CERFACS, France, May 26, 1989

Axel Ruhe, *How to Use Spectral Transformation on Sparse Nonlinear and Nonsymmetric Eigenvalue Problems*, Gothenburg University, Sweden, June 15, 1989

William Gropp, *Local Uniform Mesh Refinement and Domain Decomposition*, Yale University, July 27, 1989

Ilse Ipsen, *Systolic Computation of Uniform Recurrence Equations in One Variable*, Yale University, August 31, 1989

Lennert Johnsson, *A Data Parallel Supercomputer*, Yale University and Thinking Machines, October 3, 1989

Daniel B. Szyld, *Sequential and Parallel Solutions of the Generalized Eigenvalue Problem*, Duke University, November 7, 1989

Dan Pierce and John Lewis, *Multifrontal Householder QR Factorization*, Boeing Computer Services, November 30, 1989

Gautam Shroff, *Parallel Jacobi-like Algorithms for the Algebraic Eigenvalue Problem*, Rensselaer Polytechnic Institute, December 1, 1989

A. Singh, *Developing Distributed Applications Using a Network of Workstations: The Frameworks Approach*, University of Alberta January 18, 1990

5.8 University Affiliates Program

We have an active affiliates program for colleges and universities interested in using the ACRF multiprocessing systems. Current members include

- Australian National University
- California Institute of Technology
- Cornell University
- Drexel University
- Memorial University of Newfoundland, Canada
- Michigan State University
- North Carolina State University
- Northern Illinois University
- Northwestern University
- Oregon State University
- Purdue University
- University of Alabama at Birmingham
- University of Chicago
- University of Illinois - Chicago
- University of Illinois - Urbana-Champaign
- University of Iowa
- University of Michigan
- University of Tennessee

- University of Tulsa
- Vanderbilt University
- Western Michigan University
- Youngstown State University

5.9 Industrial Affiliates Program

To complement our academic affiliates program, we have established an industrial affiliates program. The purpose of the program is to provide industry with access to a variety of experimental machines and to bring together users and manufacturers of parallel processors. ARCH Development Corporation is directing the program.

To date, we have 15 associate and affiliate members:

- Active Memory Technology
- Alliant Computer Systems
- Ardent Computer Corporation
- BBN Advanced Computer Systems
- Convex Computer Corporation
- Encore Computer Systems
- Epoch Systems
- Intel Scientific Computers
- Litton Data Systems
- MasPar Computer Corporation
- Mercury Computer Systems
- NeXT, Inc.
- Phillips Petroleum
- Sequent Computer Systems
- Thinking Machines Corporation

5.10 Summer Institute

On September 5-15, 1989, we hosted the third **Summer Institute in Parallel Programming** to familiarize university researchers with new techniques in high-performance computing. Twenty-five graduate students and postdoctoral researchers were selected to participate in the institute, which was sponsored in part by the National Science Foundation and in part by the Department of Energy.

Invited speakers included Arvind (MIT), D. Austin (Department of Energy); M. Chandy (Caltech); T. DeFanti (University of Illinois, Chicago); D. Gelernter (Yale University); J. Gurd (University of Manchester); K. Kennedy (Rice University); A. Nicolau (University of California, Irvine); B. Smith (Tera Computer); and G. Steele (Thinking Machines Corp.). Each invited speaker conducted a two-and-a-half-hour session, covering such topics as the Tera computer and Connection Machine, programming support environments, program composition, and pipeline architectures. In addition, Argonne research staff conducted lectures on such topics as parallelizing compilers, programming environments, and the monitor-macros package. The participants were also given hands-on experience on the ACRF machines.

Based on the success of these institutes, the National Science Foundation has already agreed to provide partial funding for next year's program.

A report of the workshop is documented in ANL-89-136.

5.11 Bulletins

For our ACRF users, we continue to produce a periodic bulletin called *Adventures in Parallelism*. During 1989, we mailed out three issues. Our objective is to let users know of new projects, equipment, and research results in parallel computing associated with our ACRF.

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