Distribution Category:
Mathematics and Computers
(UC-32)

ANL--82-26

ANL-82-26

DE82 014449

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

APPLIED MATHEMATICAL SCIENCES RESEARCH AT ARGONNE

April 1, 1981 - March 31, 1982

Applied Mathematics Division

Paul C. Messina, Associate Division Director
Richard J. Royston, Division Director

edited by

Gail W. Pieper

This work was supported by the Applied Mathematical Sciences Research Program (KC-04-02) of the Office of Energy Research of the U.S. Department of Energy.

CONTENTS

ABSTRACT

This report reviews the research activities in Applied Mathematical Sciences at Argonne National Laboratory for the period April 1, 1981, through March 31, 1982. The body of the report discusses various projects carried out in three major areas of research: applied analysis, computational mathematics, and software engineering. Information on section staff, visitors, workshops, and seminars is found in the appendices.

APPLIED MATHEMATICAL SCIENCES RESEARCH AT ARGONNE

April 1, 1981 - March 31, 1982

The goals of research in the Applied Mathematical Sciences program at Argonne are to discover, adapt, or apply techniques in mathematics and computer science that promise to be useful in solving scientific and engineering problems. Our approach involves the formulation of new analytical and numerical methods, the design of computational algorithms, their implementation in computer programs, and their application in practical problems. We also seek to develop concepts and techniques that will eventually make feasible the design of computer-based systems capable of tasks such as program verification or power-plant safety analyses. Our research is organized in three areas: applied analysis, computational mathematics, and software engineering. We also operate a Research Computing Facility as a special project. This facility provides a computing environment for our mathematical research and for collaborative studies among AMS-funded groups.

Our activities, which range from studies of flow instabilities in reactor systems to automated deduction, reflect a mix of theory and application. For example, our research in elementary functions not only has yielded superior algorithms but also has made test programs available for benchmarking and certification of new Fortran libraries. The analysis of optimization methods for modeling analysis has also involved design of the General Systems Modeling Program, which is now being used in the Engineering Division. Quadrature research, too, comprises both the development of numerical integration techniques and their dissemination through the *Quadrature Users' Guide*.

The collaborative nature of our research deserves special note. Individual projects in fact involve close interaction among our staff. The software engineering activities illustrate this point. Research in automated program transformation motivated the development of the TAMPR system, which in turn was used to restructure the LINPACK codes.

Another important component of our research is interaction with universities and other research institutions. An outstanding example is the Toolpack project. Organized in 1979, it involves collaboration with three universities, three commercial organizations, and another government laboratory. Other collaborative efforts include work on bifurcation and stability problems with B. J. Matkowsky of Northwestern University, research in optimization and software basics with R. Crane of the RCA David Sarnoff Research Center, and use of our theorem prover (developed with researchers at Northern Illinois University) to design new circuits at the Illinois Institute of Technology and to analyze control systems software for Draper Laboratories.

This report reviews the research activities in the Applied Mathematical Sciences Section for the period April 1, 1981 - March 31, 1982. During this period, significant progress was made in several areas:

1. The first two layers of a new "logic machine architecture" for theorem-proving programs were implemented. The modular design of this architecture will provide, for the first time, the opportunity to experiment with theorem-proving programs that incorporate different strategies and methods. Its transportable implementation should also make it available in a variety of computing environments.

2. A new algorithm for minimizing a quadratic function on a hyperellipsoid was designed. The algorithm requires, on the average, only 1.6 iterations to find a nearly optimal global solution.

3. The first testing of Toolpack was successfully completed on our Vax/Unix system. The package is expected to be released to test sites by late 1982.

4. Encouraging results were obtained from experiments in using our automated reasoning program AURA for design verification of binary logic circuits. The design of four-, eight-, and sixteen-bit adders was verified These experiments indicate that it may be possible to use AURA as a component of design automation systems.

5. The transformation component of TAMPR was implemented on the Vax/Unix system. This research is the first step in the design of a transportable version of TAMPR.

6. An algorithm was constructed based on the use of pre-conditioned conjugate gradients. The algorithm requires no additional storage beyond that of the original linear system.

7. Work continued on the research monograph entitled *Spectral Methods in Linear Transport Theory*. Among the new results obtained was the development of a theory of spectral representations and factorization methods for certain classes of nonhermitian operators.

8. A new and more robust algorithm for complex division was discovered during development of test programs for complex arithmetic packages.

These and other activities detailed below reflect the efforts of a permanent scientific staff of 20, many of whom work in more than one area of research. A complete list of section members, their publications, and their professional activities is provided at the back of this report. Also included is a list of faculty, students, and consultants who visited Argonne to conduct seminars, participate in workshops, or collaborate on special projects in mathematics and computer science.

I. APPLIED ANALYSIS

The essence of applied analysis research at Argonne is the application of analytical and numerical techniques to problems in the natural and engineering sciences. Current interest centers on the modeling and analysis of reaction-diffusion systems, bifurcation phenomena in combustion problems, and fluid flow problems related to loss-of-coolant analysis in reactor engineering. While specific areas of investigation may vary in response to changing DOE needs, the long-term objectives remain the same: the mathematical modeling of observable phenomena, the analysis of the mathematical model, and the interpretation of the analytical results.

A. Evolution Equations

Hans G. Kaper, Gary K. Leaf, Bernard J. Matkowsky, and Anton Zettl†*

The multitude of nonlinear evolution phenomena in scientific and engineering applications makes nonlinear evolution equations a challenging area of study. In the applied analysis program, emphasis is placed on evolution equations that arise in fluid flow and gas dynamics problems and in reaction-diffusion systems. The long-term objective is to obtain qualitative and, possibly, quantitative information about a given physical system, through the design of reliable mathematical models and the development and application of efficient solution techniques.

1. Linear Evolution Equations

Hans G. Kaper and Anton Zettl†

We continued work on a research monograph entitled *Spectral Methods in Linear Transport Theory*. This project is carried out in collaboration with C. G. Lekkerkerker (University of Amsterdam, Netherlands) and J. Hejtmanek (University of Vienna, Austria). The monograph explains the characteristic spectral features of transport operators and their implications for the solution of many problems in neutron transport, radiative transfer, the kinetic theory of gases, and plasma physics. Among the new results obtained during the past year we mention the development of a theory of spectral representations and factorization methods for certain classes of nonhermitian operators which play a role in the solution of boundary value problems in linear transport theory.

In collaboration with A. Zettl (on sabbatical leave from Northern Illinois University), we initiated two research projects in spectral analysis. The first project, which was motivated by certain boundary value problems of electron transport theory, is concerned with eigenvalue problems for indefinite Sturm-Liouville equations. Abstractly, the eigenvalue problems are of the form $Ax = \lambda Bx$, where A is an (unbounded) differential operator and B an operator of multiplication by a function that changes sign. The purpose of this project is to validate the use of eigenfunction expansions for the solution of boundary value problems. The second project is concerned with the Schrodinger and Dirac operators. One goal is to determine their spectra in terms of

* Northwestern University

† On sabbatical leave from Northern Illinois University

the coefficients and boundary conditions, another to study the qualitative (e.g., oscillatory) behavior of their eigenfunctions.

2. Bifurcation Phenomena

*Hans G. Kaper, Gary K. Leaf, and Bernard J. Matkowsky**

Experimental observations have indicated several burning modes of a solid fuel, in which a reaction front propagates nonuniformly through a cylindrical fuel element of uniform composition. This type of combustion occurs without the formation of a gas phase and may appear either as a pulsating motion, where a propagating planar reaction front pulsates periodically, or as a spinning motion, where a propagating reaction front moves in a helical motion through the sample. We have formulated a mathematical model to explain these modes as bifurcation phenomena.

Specifically, two geometrical configurations are being considered. In the first, the solid fuel sample is modeled as a cylindrical shell; burning is restricted to the lateral surface of the cylinder. In the second configuration, the fuel sample is modeled as a solid cylinder; burning occurs throughout the cylinder. In both configurations, uniformly propagating plane modes, as well as pulsating and spinning modes, are possible. The purpose of our analysis is twofold: to demonstrate that the mathematical model as formulated is adequate to describe the various combustion modes, and to predict which modes will appear in actual experiments.

B. Differential Equations

Gary K. Leaf

This activity comprises collaborative efforts with scientists in other Argonne divisions.

With T. C. Chawla from the Reactor Analysis and Safety Division, we began investigating moving mesh techniques coupled with collocation methods for solving problems in phase transitions and in fluid flow with steep fronts. Within the context of collocation methods, we considered the problems associated with using a mesh that is concentrated in the vicinity of the steep fronts and that maintains its relationship with the front during the transient behavior.

In collaboration with N. Q. Lam from the Materials Science Division, we also resumed work on radiation-induced precipitation in alloys. We are developing a mathematical model that will take into account the existence of a moving precipitate/matrix interface. This moving interface will be addressed by means of an immobilizing technique for moving boundaries.

* Northwestern University

II. COMPUTATIONAL MATHEMATICS

Computational mathematics research at Argonne involves the design and analysis of numerical algorithms, the development of special techniques to measure algorithm reliability and efficiency, and the preparation of software based on broadly applicable computational methods. Efforts focus on development of new algorithms for Bessel functions, investigation of optimization algorithms, design and dissemination of quadrature techniques, study of methods for solving partial differential equations, and development of improved techniques for solving problems in numerical linear algebra, including algorithms for vector pipeline computers. In addition, work on performance profiles for software evaluation continues, and special methods are being developed for use in systems modeling and chemical equilibrium problems.

A. Optimization

Joseph M. Cook, Burton S. Garbow, Kenneth E. Hillstrom, Michael Minkoff, Jorge J. Moré, and Danny C. Sorensen

Optimization continues to play a major role in research activities at Argonne. One part of our studies is concerned with the development of new algorithms for general optimization problems. These algorithms can then be implemented in our MINPACK collection of high-quality optimization software. Another part of our studies focuses on specially structured optimization problems that arise in specific energy applications problems. We also carry out smaller programs of research in the evaluation of mathematical software and in systems modeling.

1. MINPACK

Jorge J. Moré, Danny C. Sorensen, Kenneth E. Hillstrom, and Burton S. Garbow

MINPACK-1, a collection of optimization routines for solving systems of nonlinear equations and nonlinear least squares problems, has been well received. The National Energy Software Center has distributed more than 75 copies and IMSL more than 50. In addition, the Numerical Algorithms Group plans to include our software for systems of nonlinear equations in the next version of their library.

We continued our investigations on the use of symbolic differentiation algorithms to obtain analytic expressions for derivatives. Specifically, we compared the JAKE program of B. Speelpenning, the TAYLOR and GRADIENT programs of B. Kedem, and the MACSYMA and EQSYSTM systems. Our comparison shows that JAKE is the most powerful and easy to use; its main drawback is that it is not portable. We were able to prepare a version of JAKE on the Unix version of Fortran 77, but future efforts will depend on the availability of Fortran 77 compilers.

The calculation of the step between iterates in trust region methods for unconstrained optimization requires an algorithm to minimize a quadratic function on a hyperellipsoid. We completed work on this algorithm and published our results in ANL report 81-83. An unusual aspect of these results is that the algorithm is guaranteed to find a nearly optimal global solution in a finite number of iterations; such solutions to nonlinearly constrained problems are often impossible to find, even if the objective function is quadratic. The numerical results for our implementation of this algorithm were also impressive: On the average, a call to our subroutine required only 1.6 iterations.

In large-scale optimization, we have been collaborating with T. Coleman (Cornell University) in a study of (unsymmetric) sparse Jacobian matrices. Our results, described in ANL report 81-39, show that the estimation of sparse matrices can be interpreted as a graph coloring problem and that the optimal direct estimation of Jacobian matrices is NP-complete. These results imply that the problem is just as difficult as the general graph coloring problem, and thus it it unlikely that there is an algorithm which is optimal and which executes in a polynomial amount of time. On the other hand, for sparse problems, our algorithms are linear and, on practical applications (obtained from Harwell and the David W. Taylor Naval Ship Research Establishment), are nearly always optimal.

Preliminary implementations of Newton and quasi-Newton methods for unconstrained minimization were completed. Experimental versions of the Newton and quasi-Newton methods for linearly constrained optimization were also prepared. Finally, most of the software needed for the direct estimation of sparse Jacobian matrices was developed and tested.

2. Optimization with Structure
Michael Minkoff

General mathematical programming methods are often inadequate for solving large-scale optimization problems that arise in energy systems analyses. We are therefore studying new approaches that explore the special structure of these problems. Our work during the past year involved two collaborative projects.

The first project, carried out with L. Hively (Oak Ridge National Laboratory), builds on our previous work with a mathematically similar problem for tritium data fitting. In this case, we have hundreds of ordinary differential equations to solve for each optimization function. We successfully adapted VMCON to the specific problem structure and obtained optimal design parameters that not only were better than previous results but also consumed less than one quarter of the computation time.

Our primary work, carried out with R. Land and M. Blander of the Chemical Engineering Division, involved calculating the concentrations of chemical compounds at chemical equilibrium. The calculation, which is frequently encountered and mathematically difficult, can be posed as the minimization of Gibbs' free energy subject to mass balance constraints. It is usually solved either as a minimization problem or as the solution of a nonlinear system of equations that arise from application of the Kuhn-Tucker conditions. The latter approach, which often involves heuristic techniques based on features found in specific problems, may fail when dealing with new problem classes. The former approach can handle a broad class of problems, but cannot obtain accurate estimates for trace concentrations well below machine precision. Our effort involved exploiting the use of duality in geometric programming. It is known that when only gaseous species occur and are modeled as an ideal gas, the Gibbs problem is a dual geometric programming problem. When the corresponding primal GP problem is solved, the trace concentrations are determined to high accuracy. We used the primal geometric programming software GGP of R. Dembo (Yale University), in conjunction with our previously developed thermodynamic database, to solve several chemical equilibrium problems. The approach was then extended to handle chemical solutions as well as ideal gas, and/or liquid, and/or solid phases simultaneously and was successfully applied to several problems, including some that had not been previously solved.

3. Systems Modeling
Joseph M. Cook

Several years ago an executive systems modeling program was designed for use in optimized models of fusion power plants. In particular, strategies for constrained optimization problems were modified to interface with elements in MINPACK as part of a parameter optimization study of the theta-pinch reactor. More recently, recognizing the need for a generalization, we developed the General Systems Modeling Program (GSMP). In addition to overall model-organization and control, GSMP provides such features as parameter sweeps, sensitivity analysis, and user-tested error diagnostics.

During this period we enhanced the capabilities of GSMP by incorporating chance-constrained programming for system reliability and risk assessment, as well as linear programming for large, linearized component models. In addition, we expanded the network flow modeling capabilities and used the code, in collaboration with V. Minkov of the Engineering Division, to model thermal energy systems. GSMP is now publicly available through the National Energy Software Center.

B. Approximations and Software Basics
William J. Cody, Jr. and Michael Minkoff

Our work on Bessel functions has two objectives: to survey all publicly available software for Bessel functions and to prepare a reasonably complete collection of transportable programs to supplement those in FUNPACK. We finished, documented, and submitted to the AMD software library a transportable program, RIBESL, for evaluating modified I Bessel functions of the first kind for real argument and order. We also prepared a transportable Fortran program for the gamma function, as well as a transportable test program. In addition, work began on a companion program, RJBESL, for evaluating the J Bessel function for real order and argument.

We extended the testing techniques developed for the *Software Manual for the Elementary Functions* to programs for testing the complex arithmetic packages that accompany standard Fortran compilers. During this research, we discovered a more robust algorithm for complex division.

In collaboration with R. Crane (RCA David Sarnoff Research Center) we surveyed the literature and software on monovariate and multivariate fitting. We found little portable software for constrained spline data fitting, graphics, or statistical sensitivity measures. We acquired the most relevant software package, DATFIT, from J. Lathrop (Sandia Laboratories, Livermore) and installed it on our Research Computing Facility.

C. Quadrature
James N. Lyness

The present thrust of our quadrature research comprises both quadrature technique design and quadrature technique dissemination.

In the area of design, work continued with L. Gatteschi of the University of Turin, Italy. We established the existence of quasi-degree quadrature rules and determined some of their elementary properties. An investigation into methods for calculating Fourier transform functions was undertaken.

In the area of dissemination, we continued to work on the ***Quadrature Users' Guide***. This is a problem-oriented manual, providing references on how to approach various quadrature problems. The first section, which deals with the calculation of Fourier coefficients, was distributed as a technical memorandum.

D. Linear Algebra
James M. Boyle, Jack J. Dongarra, Gary K. Leaf, and Michael Minkoff

Investigations in numerical linear algebra focus on the design of algorithms that can solve linear equations more accurately and more efficiently. In addition to continuing work on the LINPACK codes, we began investigating the task of producing a machine-independent version of EISPACK. We are also exploring new methods for improving the accuracy of eigenpairs and for solving sparse, non-symmetric linear systems; and we are studying new algorithms for vector pipeline computers.

1. LINPACK and EISPACK
Jack J. Dongarra and James M. Boyle

Our major activity involved implementing new subroutines to test the feasibility of an out-of-core version of the LINPACK codes. The new design changes the order in which operations or transformations are performed, thus permitting rapid access to secondary storage data. We also implemented the program transformations needed to replace Basic Linear Algebra Subprograms (BLAS) by in-line code.

During the past year it became apparent that further work on the eigenvalue package EISPACK was desirable. A large number of sites need a Vax version of EISPACK, which was not provided at the time EISPACK was completed because the Vax did not exist. We began studying the effort involved in producing a machine-independent version of EISPACK. This would be a replacement version, perhaps including some additional routines to enhance efficiency in certain environments.

2. Eigenvalue and Eigenvector Refinements
Jack J. Dongarra

We continued work on an algorithm to improve the accuracy of a simple eigenvalue/eigenvector pair. The algorithm uses the orthogonal triangularization factors from the QR algorithm to minimize the work needed in improving the accuracy. Extended precision is used only at critical points in the algorithm. The method requires few iterations and converges quickly if the approximation is close to the true eigenpair. Software implementing this algorithm is under development.

3. Non-Symmetric Linear Systems
Jack J. Dongarra, Gary K. Leaf, and Michael Minkoff

We initiated a research effort into the iterative solution of certain classes of sparse, non-symmetric linear systems. These systems are central to two-phase flow calculations that arise in reactor analysis and safety studies. We surveyed existing methods for solving such systems, successfully adapted a technique involving conjugate gradients combined with incomplete factorization (previously used for symmetric systems) to non-symmetric systems, and created new variants of the approach. We also investigated how well an incomplete factorization can be used in conjunction with acceleration techniques, and compared the algorithm to other methods. The results were published in ANL report 81-71.

4. Algorithms for Vector Pipeline Computers
Jack J. Dongarra

During the last quarter of 1981, J. Dongarra spent several months at the IBM Watson Research Center. The visit generated new ideas for research on algorithms for a vector pipeline architecture. In collaboration with scientists at IBM, we began investigating how algorithms for linear algebra can be restructured to take advantage of certain architectural features and still perform efficiently on conventional machines. Specifically, we are studying the effects of architectural constructs such as pipelining, chaining, and overlapping of functional units.

E. Numerical Solutions of Partial Differential Equations
Gary K. Leaf and Michael Minkoff

This effort is concerned with the analysis of methods and software design for solving systems of nonlinear partial differential equations, including parabolic, mixed parabolic-elliptic, and some hyperbolic systems. We use the method of lines to reduce a system of PDEs to a system of ordinary differential equations. Reduction is achieved by means of a Galerkin procedure. The resulting system of ODEs is solved with a modified version of the GEARIB package developed by Hindmarsh at Lawrence Livermore Laboratory. The initial software implementation developed to test our techniques resulted in the design of the DISPL1 package, as well as a more general version called DISPL2.

During this period we made one major enhancement to DISPL2 that allows arbitrary nonlinearities in the boundary conditions and in the matrix valued diffusion coefficients. This enhancement is reflected not only in the specification of these nonlinearities but also in the correct treatment of the Frechet derivatives of the nonlinearities.

We also continued to interact with DISPL users, specifically with F. Hagarty of Suntech Corp. on the implementation of a two-phase turbulent flow model for describing a large-scale fluidized bed catalytic converter, and with R. Amaneta of RCA David Sarnoff Research Center on a semiconductor problem involving two-dimensional p-n junctions.

III. SOFTWARE ENGINEERING

Software Engineering research at Argonne is concerned primarily with difficulties that arise in designing and producing highly reliable, easily usable computer software. Activities range from theoretical work on automated reasoning and program transformations to application of software engineering techniques in the production of program packages like LINPACK and Toolpack. In addition, Argonne is participating in work on standards for Fortran and PL/I.

Having such a spectrum of activities makes it possible for Argonne scientists both to develop new software production tools and strategies and to test them in a working environment. For example, the TAMPR system was developed in the research on automated program transformations; it was subsequently used to produce LINPACK, to prepare input for the automated theorem prover, and to study data and programming abstractions. In turn, these applications of TAMPR are generating input for the continuing research on program transformation methods.

A. Program Development, Transformation, and Verification

James M. Boyle, Wayne R. Cowell, Kenneth W. Dritz, John R. Gabriel, Burton S. Garbow, Terence Harmer, Ewing L. Lusk, M. N. Muralidharan†, Brian T. Smith, and Lawrence T. Wos*

The ultimate goal of our work on software tools and techniques is to reduce the cost of producing high-quality mathematical software — whether it be new software for inclusion in a package or an adaptation of existing software for a particular application program. Emphasis is placed on automatically creating reliable variants of software routines, assisting in their conversion to different computers, and analyzing program structure. Automated techniques for verifying the logical soundness of software are also under investigation.

1. Automated Reasoning

Lawrence T. Wos, Brian T. Smith, Ewing L. Lusk, and John R. Gabriel

Our research in automated reasoning yielded several new results. First, we generalized the concept of weighting —a method by which the user imparts to the reasoning program some intuitive understanding of a problem and, thus, of the paths to its solution. The generalization of weighting enables one to instruct the program to prefer certain relationships among the constructs present in the problem.

Second, we formulated a set of inference rules called linked inference. This formulation applies to a number of existing inference rules in automated deduction. With its use one is able to make more significant steps in a single inference.

Third, we extended the theoretical uses of demodulation. Demodulation until now has been employed exclusively as a rewrite rule, used for canonicalization and

* Undergraduate student appointment

† Postdoctoral appointment

simplification. We defined sets of demodulators that enable set theory to be handled more efficiently and naturally, permit the program to find generalizations of a set of facts, enable a case analysis to be conducted automatically, and allow certain tedious bookkeeping and updating tasks to be dispatched without causing the program to stray from the main line of inquiry.

In another area of research, we began work on an abstract architecture called LMA (Logic Machine Architecture) for automated deduction systems. LMA was implemented as a portable, flexible, and user-oriented collection of programs written in Pascal. It consists of a carefully structured sequence of software layers, each of which is a package of tools for constructing the next layer. The first two layers, containing primitive abstract data types and fundamental automated deduction operations, were completed. Substantial progress was made on the third layer — a collection of inference mechanisms, rewrite rules, and related procedures. When it is completed, the user will be able to test radically new ideas in representation, axiom systems, and strategy and inference rules and to construct automated deduction programs tailored to a particular need.

To evaluate the effectiveness of AURA and LMA, we attempted to solve a number of problems in abstract algebra, formal logic, and design of multiple-valued and binary logic circuits. In all three areas excellent results were obtained, including the solution of several open problems and conjectures. Finally, in a project called AURORA (AUtomated Reasoning On Reactor Analysis), we developed techniques to describe the Reactor Trip System in the TREAT Upgrade Reactor, and combined the resultant database with the automated reasoning system to reason about the effects of various requests to scram the reactor. The program was able to prove, as required for plant licensing, that single component failures could not inhibit shutdown.

2. Tools for Numerically Oriented Fortran Programs

Wayne R. Cowell, James M. Boyle, Kenneth W. Dritz, and Burton S. Garbow

The aim of the Toolpack project is to produce a unified collection of Fortran-oriented software tools and a packaging and operating environment within which new tools may be added to the collection. Argonne is playing a lead role in defining the objectives and organization of the project, establishing a liaison with funding agencies, and identifying priorities for future work. In addition, Argonne is involved in tool development and testing.

Considerable progress was made in the construction of Toolpack components and in the design of the command language and file system incorporating those components. Release -1 was successfully tested at Argonne in November on the Vax/Unix system. Further enhancements are under way, and we expect Release 0 to be sent to the test sites by mid 1982.

Argonne scientists began converting the Lisp implementation of the TAMPR transformer to Fortran, prepared several chapters detailing how to write transformations, and designed a preliminary version of the TAMPR recognizer to be used with the transformer.

3. Automated Program Transformation

James M. Boyle, Kenneth W. Dritz, Terence Harmer, and M. N. Muralidharan†*

We are investigating methods for specifying, implementing, and proving the correctness of program transformations. Particular attention is given to collections of transformations that are applicable to large classes of programs and that substantially modify them.

Our current emphasis is on making the TAMPR system transportable. Toward this goal, we (a) modified the transformation interpreter (written in Lisp) to run under the Vax/Unix system; (b) began work on a transportable recognizer, using the LR parser-generator by Wetherell and Shannon (Lawrence Livermore National Laboratory) and the FSCAN lexer-generator by Clemm (University of Colorado); (c) studied the feasibility of using TAMPR to transform the Lisp implementation of the TAMPR transformer into a Fortran program that simulates recursion by use of a stack and computed GO-TO statements (using support routines from the Lisp F3 system); and (d) prepared several sections of a manual documenting how to write TAMPPR transformations.

In addition, we wrote three major new sets of transformations. One of these creates specification statements for any identifiers used in a Fortran program but not explicitly declared. Another implements complex arithmetic as an abstract data type, by converting operations on complex data to operations on pairs of reals. The third implements quaternions as an abstract data type. This last application of TAMPR was motivated by a problem involving time-reversal symmetry that arose in the Solid State Sciences Division at Argonne. We are currently testing this set of transformations and comparing the efficiency of the quaternion versions of programs with other, more traditional approaches to solving the problem. This work is being conducted with W. Barth (undergraduate honors program participant).

4. Abstract Programming

James M. Boyle, Kenneth W. Dritz, M. N. Muralidharan†, and Brian T. Smith

The study of abstract programming was motivated by the successful use of slightly abstract program formulations in LINPACK and by continuing studies of the transportability of numeric and non-numeric software. Its goals are (a) to investigate abstraction as a technique for producing reliable, highly adaptable software for basic computations and (b) to exploit adaptability as a technique for optimizing the software for different applications and computers.

Our main activity has involved a study in the abstract formulation of non-numeric programs. Our purpose is to investigate the possibility of writing transformations that transform programs written in pure functional Lisp (of which the TAMPR recognizer is an example) into Fortran. We wrote a set of transformations that convert recursive Lisp programs which use only the integer data type (e.g., the factorial and Fibonacci functions) to non-recursive executable Fortran programs. This work was conducted with D. Smith (undergraduate honors program participant). We are

* Undergraduate student appointment

† Postdoctoral appointment

currently extending these transformations to handle Lisp programs using the list data type; we intend to make use of utility functions (garbage collector, read and print routines) adapted from those in the Lisp F3 system of Nordstrom (Upsala University).

In the area of abstract formulation of numerical programs, we wrote the transformations implementing the complex and quaternion data types discussed under Automated Program Transformation above.

B. Language Activities

Kenneth W. Dritz, Paul C. Messina, and Brian T. Smith

Language research studies address the problem of ensuring that programming languages meet the diversified and changing needs of their users. Argonne is participating in three projects: revisions of ANS Fortran, revisions of ANS PL/I, and design of a proposal for a common programming language for use in the Department of Energy. Our special concern in these projects is the suitability of the language for numerical computations.

1. Fortran Standards Committee

Brian T. Smith

Since the 1977 revision of ANS Fortran, the X3J3 Fortran Standards Committee of the American National Standards Institute (ANSI) has been considering revisions of the standard so that the language meets the changing needs of its users. During this period we presented proposals to the committee to incorporate a general floating-point facility; most of these proposals were accepted for the basis document describing the proposed Fortran revision.

2. PL/I Standards Committee

Kenneth W. Dritz

To represent the interests of those using large scientific computers, Argonne and SHARE Inc. are jointly sponsoring a membership on the ANSI technical committee X3J1 (PL/I), which is revising the American National Standard for PL/I.

During this period we prepared a document describing an integrated collection of six extensions for numerical analysis. Of these, the most significant are the addition of built-in functions for environmental inquiry, the enlargement of the set of built-in functions permitted in "restricted expressions" (constant expressions that a compiler must evaluate at compile time), and the inclusion of restricted expressions in the syntax of the precision attributes. Together, these extensions will facilitate the tailoring of mathematical software to new and different environments, in some cases even resulting in self-adapting programs.

3. Language Working Group

Paul C. Messina and Brian T. Smith

The Language Working Group was formed by the DOE-established Advanced Computing Committee to recommend a common programming language for the national laboratories. The group responded by designing a set of extensions to ANS Fortran. It also recommended that a "rehostable" Fortran compiler and library be implemented to support the language. The group's suggestions were presented in a report designed for the users of the language.

The LWG has now shifted its role to that of information exchange on scientific programming languages, with particular emphasis on tracking Fortran standards activities. In its new role, it is under the supervision of the DOE Scientific Computing Information Exchange Council.

IV. RESEARCH COMPUTING FACILITY

The Research Computing Facility (RCF) is a special project whose goals are to provide a computing environment well matched to the research needs of our AMS program and to facilitate collaboration with AMS-funded groups at universities and other national laboratories. The RCF was established in 1981 with the installation of a Vax 11/780 minicomputer manufactured by Digital Equipment Corporation. The Vax is running the Unix operating system developed by Western Electric Corporation and enhanced by the University of California, Berkeley. The system is connected to Argonne's central computing facility through the ANL Intra Laboratory Network and to the Telenet commercial network for nationwide access; we also expect to connect the Vax to the ARPA (Advanced Research Projects Agency) network.

The RCF has already proved useful to most of our research activities. Experiments in computational mathematics and software evaluation are under way, as well as development of new versions of the automated reasoning system and the TAMPR transformation program. In addition, many of our technical publications are being prepared with the Unix document-preparation tools.

Appendix A

PERMANENT STAFF

J. M. Boyle, *Ph.D.*, Northwestern University, 1970

W. J. Cody, Jr., *M.A.*, University of Oklahoma, 1956; *D.Sc. (Hon.)*, Elmhurst College, 1977

J. M. Cook, *Ph.D.*, University of Chicago, 1951

W. R. Cowell, *Ph.D.*, University of Wisconsin, 1954

J. J. Dongarra, *Ph.D.*, University of New Mexico, 1980

K. W. Dritz, *M.S.*, Massachusetts Institute of Technology, 1967

J. R. Gabriel, *M.S.*, University of Otago, New Zealand, 1953

B. S. Garbow,* *M.S.*, University of Chicago, 1952

K. E. Hillstrom, *M.S.*, Northwestern University, 1957

H. G. Kaper, *Ph.D.*, Rijksuniversiteit, Groningen, 1965

G. K. Leaf, *Ph.D.*, University of Illinois, 1961

E. L. Lusk, *Ph. D.*, University of Maryland, 1970

J. N. Lyness, *D. Phil.*, Oxford University, 1957

P. C. Messina,† *Ph.D.*, University of Cincinnati, 1972

M. Minkoff, *Ph.D.*, University of Wisconsin, 1973

J. J. Moré, *Ph.D.*, University of Maryland, 1970

G. W. Pieper, *Ph.D.*, University of Illinois, 1969

B. T. Smith, *Ph.D.*, University of Toronto, 1969

D. C. Sorensen, *Ph.D.*, University of California, San Diego, 1977

L. T. Wos, *Ph.D.*, University of Illinois, 1957

* Joint appointment, Systems and Applications Section, Applied Mathematics Division
† Associate Division Director

Appendix B

TEMPORARY STAFF

Postdoctoral Appointments

M. N. Muralidharan, *Ph.D.*, Indian Institute of Technology, Kanpur, India, January 1982

Faculty Research Leave Appointments

A. Wojcik, *Ph.D.*, University of Illinois, 1971
(on leave from the Illinois Institute of Technology)

A. Zettl, *Ph.D.*, University of Tennessee, 1964
(on leave from Northern Illinois University)

Appendix C

PROFESSIONAL ACTIVITIES

Members of the section participated in the following professional activities during the period April 1, 1981 - March 31, 1982.

W. J. Cody	Associate Editor, Transactions on Mathematical Software Member, International Federation for Information Processing Working Group 2.5 for Mathematical Software Member, IEEE Subcommittee for Floating-Point Arithmetic Chairman, IEEE Standards Subcommittee for Radix and Format Independent Floating Point Standard
W. R. Cowell	Council Chairman, Toolpack Project
J. J. Dongarra	Co-chairman, Contributed Papers, Program Committee SIAM 1981 Fall Meeting
K. W. Dritz	Member, X3J1 PL/I Standards Committee Member, SHARE PL/I Project
J. R. Gabriel	Member, American Society of Mechanical Engineers Process Control Computer Committee
H. G. Kaper	Associate Editor, Integral Equations and Operator Theory Chairman, Program Committee SIAM 1981 Fall Meeting Member, SIAM National Program Committee SIAM Visiting Lecturer
J. N. Lyness	Associate Editor, Mathematics of Computation Associate Editor, SIAM Journal on Numerical Analysis Co-chairman, Contributed Papers, Program Committee SIAM 1981 Fall Meeting
P. C. Messina	Chairman, DOE Advanced Computing Committee Language Working Group Member, Program Committee SIAM 1981 Fall Meeting
M. Minkoff	Area Editor, SIGMAP Newsletter

J. J. Moré	Associate Editor, SIAM Journal on Numerical Analysis Associate Editor, SIAM Journal on Scientific and Statistical Computing Associate Editor, Numerische Mathematik
G. W. Pieper	Lecturer, Illinois Benedictine College
B. T. Smith	Chairman, SIGNUM Fortran Committee Member, DOE Advanced Computing Committee Language Working Group Member, International Federation for Information Processing Working Group 2.5 for Mathematical Software Member, X3J3 Fortran Standards Committee

Appendix D

PRESENTATIONS

The following list reflects articles published, reports distributed, and talks presented during the period April 1, 1981 - March 31, 1982.

Publications

G. F. Berry, J. M. Cook, and C. B. Dennis, "Applications of Polyalgorithmic Optimization to MHD Power Plant Design," International Journal of Energy Systems, SFE-81-85, May 1981

J. J. Dongarra, "LINPACK Timings on the CRAY-1," *Tutorial in Parallel Processing*, R. H. Kuhn and D. A. Padua, eds., IEEE, 1981, pp. 363-380

H. G. Kaper, "Automorphism Theorems and Half-Range Theory," Progress in Nuclear Energy, **8**, 107-116 (1981)

H. G. Kaper, "Long-Time Behavior of a Nuclear Reactor," *Spectral Theory of Differential Operators*, J. W. Knowles and R. T. Lewis, eds., North-Holland Publishing Co., 1981

H. G. Kaper, "Symposium to Consider Transport Phenomena," SIAM News, **14**, 1-2 (1981)

G. K. Leaf and M. Minkoff, "DISPL2: Software System for One and Two Dimensional Kinetics-Diffusion Problems," *Advances in Computer Methods for Partial Differential Equations*, IV, R. Vichnevetsky and R. Stepleman, eds., IMACS, 1981, p. 343 (abstract)

E. Lusk, "Can Computers Prove Theorems?" Abstracts of the American Mathematical Society, **2**, 336 (1981)

M. Minkoff, "Methods for Evaluating Nonlinear Programming Software," *Nonlinear Programming*, Vol. 4, O. L. Mangasarian, R. R. Meyer, and S. M. Robinson, eds., Academic Press, 1981, pp. 518-548 (also AMD Technical Report 376)

J. J. Moré, B. S. Garbow, and K. E. Hillstrom, "Algorithm 566: FORTRAN Subroutines for Testing Unconstrained Optimization Software," ACM Trans. on Math. Soft., **7**, 136-140 (1981)

J. J. Moré, B. S. Garbow, and K. E. Hillstrom, "Testing Unconstrained Optimization Software," ACM Trans. on Math. Soft., **7**, 17-41 (1981)

D. C. Sorensen, "An Example Concerning Quasi-Newton Estimation of a Sparse Hessian," SIGNUM Newsletter, **16**, 8-10 (1981)

S. Winker, L. Wos, and E. Lusk, "Semigroups, Antiautomorphisms, and Involutions: A Computer Solution to an Open Problem, I," Math. of Comp., **37**, 533-545 (1981)

L. Wos, "Solving Open Questions in Mathematics with an Automated Theorem-proving Program," Abstracts of the American Math. Society, **2**, 336 (1981)

L. Wos, S. Winker, and E. L. Lusk, "An Automated Reasoning System," *Proc. of the National Computer Conference*, Chicago, Ill., May 4-7, 1981

Reports

T. F. Coleman and J. J. Moré, *Estimation of Sparse Jacobian Matrices and Graph Coloring Problems*, ANL-81-39

J. J. Dongarra, "Improving the Accuracy of Computed Singular Values," ANL-82-4

J. J. Dongarra, G. K. Leaf, and M. Minkoff, *A Preconditioned Conjugate Gradient Method for Solving a Class of Non-Symmetric Linear Systems*, ANL-81-71

J. J. Dongarra, C. Moler, and J. H. Wilkinson, *Improving the Accuracy of Computed Eigenvalues and Eigenvectors*, ANL-81-43

G. K. Leaf and M. Minkoff, *Extensions of DISPL to R-θ Geometry*, ANL-81-81

B. J. Lucier, *Dispersive Approximations for Hyperbolic Conservation Laws*, ANL-81-74

B. J. Lucier, *The Effects of Curvature on Asymmetric Steady States in Catalyst Particles*, ANL-81-7

B. J. Matkowsky, L. J. Putnick, and E. L. Reiss, *Buckling of a Thin Initially Wrinkled Rectangular Plate*, ANL-81-51

B. J. Matkowsky, L. J. Putnick, and E. L. Reiss, *Secondary States of Vibrating Plates*, ANL-81-49

J. J. Moré and D. C. Sorensen, *Computing a Trust Region Step*, ANL-81-83

J. J. Moré and D. C. Sorensen, *Newton's Method*, ANL-82-8

J. Y. Wang and B. S. Garbow, *Guidelines for Using the AMDLIB, IMSL, and NAG Mathematical Software Libraries at ANL*, ANL-81-73

Technical Memoranda

W. J. Cody, *Floating Point Parameters, Models, and Standards*, T.M. 389 (1981)

W. J. Cody, *FUNPACK—A Package of Special Function Subroutines*, T.M. 385 (1981)

J. N. Lyness, *QUG1: Trigonometric Fourier Coefficients*, T.M. 370 (1981)

Oral Presentations

J. M. Boyle, "Program Transformation and Language Design," TC-2 Working Conference —Relationship between Numerical Computation and Programming Languages, Boulder, Colorado, August 3-7, 1981

B. Char, "Using Lie Transformation Groups to Find Closed Form Solutions to First Order Ordinary Differential Equations," ACM SYMAC Conference, Snowbird, Utah, August 4-6, 1981

W. R. Cowell, "Partnerships in Software," CBMS Symposium on Energy Research and Mathematical Sciences, San Francisco, January 9, 1982 (invited talk)

J. J. Dongarra, "Scientific Computing and Mathematical Software," De Vry Institute, May 17, 1981

J. J. Dongarra, "Improving the Accuracy of Computed Singular Values," Gatlinburg 8 Meeting on Linear Algebra, Oxford, England, July 6, 1981, and SIAM 1981 Fall Meeting, Cincinnati, October 26-28, 1981

J. J. Dongarra, "Improving the Accuracy of Computed Matrix Eigenvalues and Eigenvectors," IBM T. J. Watson Research Center, Yorktown Heights, New York, November 1981

J. J. Dongarra, "LINPACK, Mathematical Software to Solve Linear Systems of Equations," Exxon Research and Engineering Co., Linden, New Jersey, December 1981

J. R. Gabriel, "A Perspective on Software Documentation and Use," National Bureau of Standards Information Processing Standards within the Federal Government, Gaithersburg, March 2-3, 1982

K. E. Hillstrom and J. J. Moré, "On the Estimation of Noise," NATO Advanced Research Institute on Nonlinear Optimization, Cambridge, England, July 13-24, 1981

H. G. Kaper, "Long-Time Behavior of a Nuclear Reactor," Conference on Spectral Theory of Differential Operators, Birmingham, Alabama, March 26-28, 1981

H. G. Kaper, "Spectral Analysis of the Reactor Problem," University of Illinois - Chicago Circle, April 22, 1981

H. G. Kaper, "Factorization Methods in Linear Transport Theory," Toeplitz Memorial Conference, Tel-Aviv, Israel, May 11-15, 1981 (invited talk)

H. G. Kaper, "Automorphismen und Faktorisierung," Oesterr. Mathem. Gesellschaft, Vienna, Austria, May 20, 1981

H. G. Kaper, "Wat is eigenlijk een kritische reaktor?" Univ. of Amsterdam, Neth., October 22, 1981

H. G. Kaper, "Factorization with Non-Hermitian Operators," Free University, Amsterdam, Neth., October 23, 1981

H. G. Kaper, "Recent Results in Linear Transport Theory," SIAM 1981 Fall Meeting, Cincinnati, October 26-28, 1981

H. G. Kaper, "Linear Transport Theory and an Indefinite Sturm-Liouville Problem," Northern Illinois University, DeKalb, March 19, 1982

H. G. Kaper, C. G. Lekkerkerker, and A. Zettl, "Linear Transport Theory and an Indefinite Sturm-Liouville Problem," 7th Conference on Ordinary and Partial Differential Equations, Dundee, Scotland, March 29 - April 2, 1982

J. N. Lyness, "A Note on Cubature over a Triangle of a Function Having Specified Singularities," Numerical Integration Meeting, Oberwolfach, Germany, October 9, 1981; University of Cagliari, Sardinia, October 14, 1981; and Italian National Conference on Numerical Analysis, Pavia, October 26, 1981

J. N. Lyness, "Has Numerical Differentiation a Future?" University of Hobart, Australia, December 4, 1981, and University of Melbourne, Australia, December 18, 1981

P. C. Messina, "Experiences in Establishing a Small Scientific Computer Center," Seminar, Mathematics Department, University of Naples, Sept. 15, 1981

P. C. Messina, "Proposed Extensions to Fortran for Mathematical Software," Seminar, Mathematics Department, University of Naples, Sept. 21, 1981

P. C. Messina, "The Role of Computer Centers in the Field of Mathematical Software," Seminar, Interfaculty Computer Center, University of Naples, Sept. 23, 1981

P. C. Messina, "Guidelines for Supporting Mathematical Software Libraries," Seminar, Interfaculty Computer Center, University of Naples, Sept. 23, 1981

P. C. Messina, "Selection and Organization of Applied Mathematics Research Projects," Seminar, Mathematics Department, University of Naples, Sept. 24, 1981

P. C. Messina, "Applied Mathematical Sciences Research at Argonne," Seminar, Università Navale, Naples, Sept. 28, 1981

P. C. Messina, "On Establishing a Research Computing Facility for Mathematicians and Computer Scientists," Seminar, Mathematics Department, University of Turin, Sept. 30, 1981

P. C. Messina, "Applied Mathematical Sciences Research at Argonne," Seminar, Centro Studi e Laboratori Telecomunicazioni, Oct. 1, 1981

P. C. Messina, "Problems and Issues in Applied Mathematics Consulting," SIAM 1981 Fall Meeting, Cincinnati, October 26-28, 1981

M. Minkoff and G. K. Leaf, "DISPL2: A Software Package for Solving One and Two Dimensional Connection-Diffusion-Kinetics Problems with General Orthogonal Geometries," 4th IMACS International Symposium on Computer Methods for Partial Differential Equations, Lehigh University, Bethlehem, Penn., June 30-July 2, 1981

J. J. Moré, "Algorithms and Software for Nonlinear Optimization," Washington University, April 3, 1981

J. J. Moré, "Notes on Optimization Software," NATO Advanced Research Institute on Nonlinear Optimization, Cambridge, England, July 13-24, 1981

D. C. Sorensen, "Trust Region Methods for Unconstrained Minimization," NATO Advanced Research Institute on Nonlinear Optimization, Cambridge, England, July 13-24, 1981

B. T. Smith, "Array Processing Features in the Next Fortran," TC-2 Working Conference —Relationship between Numerical Computation and Programming Languages, Boulder, Colorado, August 3-7, 1981

B. T. Smith, "Environmental Inquiry and General Precision Data Type Features for the Next Fortran Standard," ACM '81, Los Angeles, November 9-11, 1981

B. T. Smith and R. Veroff, "The Argonne Verification System," SIAM 1981 Fall Meeting, Cincinnati, October 26-28, 1981

R. Veroff and L. Henschen, "Application of Automatic Transformations to Program Verification," International Joint Conference on Artificial Intelligence, Vancouver, B.C., August 24-28, 1981

Appendix E

VISITORS PROGRAM

The Visitors Program encourages interactions with the applied mathematical sciences research community. Following is a list of students and visiting scientists who came to Argonne for work in mathematics and computer science during the period April 1, 1981, through March 31, 1982.

Faculty and Staff Appointments

George Davis	Georgia State University
C. Gerrit Lekkerkerker	Universiteit van Amsterdam
George Miel	University of Nevada
James White	Spelman College
Anthony Wojcik	Illinois Institute of Technology
Anton Zettl	Northern Illinois University

Graduate Student Appointments

Douglas Baxter	Stanford University
Alessandro Gatteschi	Turin Polytechnic Institute, Italy
Waldo Kabat	Illinois Institute of Technology
Bart Louhi	Northwestern University
William McCune	Northwestern University
Steven Winker	University of Illinois, Chicago Circle
Lina Yick	University of Illinois

Undergraduate Student Appointments

Wendy Barth	Coe College
Terence Harmer	Queen's University, Belfast, Ireland
Margaret Memory	North Carolina State University
Diane Smith	Canisius College
Denise Widup	Lewis University

Pre-College Program in Science and Engineering

Leroy Collins	Mendel Catholic College-Preparatory High School

Appendix F

CONSULTANTS

James Bunch	University of California, San Diego
William Davidon	Haverford College
Ewing Lusk	Northern Illinois University
Olvi Mangasarian	University of Wisconsin, Madison
Bernard Matkowsky	Northwestern University
Cleve Moler	University of New Mexico
Gary Roediger	Corporate Computer Services
J. Ben Rosen	University of Minnesota
David Thuente	Purdue University
William Waite	University of Colorado
James Wilkinson	National Physical Laboratory, England

Appendix G

MEETINGS AND WORKSHOPS

1. Toolpack Workshop and Council Meeting - April 30 - May 2, 1981

A three-day workshop and council meeting was held at Argonne to hear reports and to review technical progress associated with the collaborative Toolpack project. The meeting was coordinated by the council chairman W. Cowell. Discussions focused on the file system and command language, documentation, and testing strategy.

2. Workshop on Computer Arithmetic - May 15, 1981

Argonne hosted a one-day workshop on the proposed IEEE floating-point standard. Three talks were presented by the principal architects of the proposal. Also included were tutorials on various aspects of the standard, which has been adopted by several microprocessor manufacturers.

3. Linear Algebra Workshop - August 24-25, 1981

A two-day workshop was held at Argonne to review software available for solving various types of numerical linear algebra problems. Included were presentations on the LINPACK, EISPACK, MATLAB, SPARSPAK, and HARWELL collections.

4. SIAM 1981 Fall Meeting - October 26-28, 1981

The SIAM 1981 Fall Meeting, held in Cincinnati, was sponsored by Argonne. In attendance were more than 250 mathematicians from universities, national laboratories, and research organizations. The program included symposia on software reliability, integral equations, and transport phenomena; a panel discussion on applied mathematics consulting; and a special address on procedures used by the National Science Foundation to evaluate research proposals.

5. Toolpack Workshop and Council Meeting - November 16-18, 1981

A three-day workshop and council meeting was held at Argonne to review progress in the Toolpack project. Release -1 was tested on the Vax/Unix system, and discussions were held to plan for Release 0.

Appendix H

SEMINARS

During the period April 1, 1981 - March 31, 1982, the Applied Mathematical Sciences Section sponsored numerous seminars in mathematics and computer science. These are listed below.

R. C. Brown
The Effects of Time Lag in a Closed Loop Six Degree of Freedom Simulation of Orbital Docking
University of Alabama
April 2, 1981

A. L. Tits
A Recursive Quadratic Programming Algorithm for Semi-Infinite Optimization Problems
University of California, Berkeley
April 27, 1981

A. Zettl
How Large Can the Derivatives of a Function Be?
Northern Illinois University
May 6, 1981

R. Dembo
The Importance of Geometric Programming as a Modelling Tool
Yale University
May 7, 1981

W. Waite
Gurus and the Gullible: Comments on Programming Methodology
University of Colorado
May 27, 1981

W. Waite
How to Split a Code Generator
University of Colorado
May 28, 1981

W. Davidon
Conjugate Direction Algorithms for Conic Functions
Haverford College
June 4, 1981

J. Bunch
Updating Matrix Decompositions
University of California, San Diego
June 18, 1981

G. Paul
Studies in Vector Processor Architecture and Scientific Applications
IBM T. J. Watson Research Center
June 29, 1981

C. G. van der Laan
Programming in Algol 68 as a Host and the Usage of Fortran Program Libraries
Computing Center of the State University, Groningen, Netherlands
August 17, 1981

J. R. Greenwood
Praxis · Beyond Pascal
Thunder Systems, Inc.
August 24, 1981

C. E. Collins, Jr.
Length Dependence of Solutions of Generalized Fitzhugh-Nagumo Equations
Indiana University
August 26, 1981

D. Vallance
An Implementor's View of Fortran 77
University of Salford, England
September 8, 1981

L. C. W. Dixon
The Place of Parallel Computation in Numerical Optimization II: The Multiextremal Global Optimisation Problem
The Hatfield Polytechnic Numerical Optimisation Centre, England
September 11, 1981

G. Golub
The Total Least Squares Problem
Stanford University
October 12, 1981

I. Duff
A Multi-Frontal Approach for Solving Sparse Linear Equations
AERE Harwell, England
October 13, 1981

I. Gohberg
Wiener-Hopf Equations and Linear Systems
Tel-Aviv University, Israel
October 29, 1981

P. Pepper
A Case for Applicative Programming
Technical University of Munich, West Germany
October 29, 1981

J. H. Wilkinson
Rounding Error Analysis Without Tears
Teddington, England
November 2, 1981

J. Hejtmanek
In Search of the Dominant Eigenvalue
University of Vienna, Austria
November 5, 1981

J. B. Rosen
Large-Scale Global Minimization
University of Minnesota
November 6, 1981

F. Chatelin
Perturbation Theory and Iterative Refinement Techniques: Application to the Matrix Eigenvalue Problem
University of Grenoble, France
February 2, 1982

K. Schittkowski
Theory, Implementation, and Test of a Nonlinear Programming Algorithm
Universitat Wurzburg, West Germany
March 2, 1982

A. Eydeland
An Iterative Method for Solving Nonlinear Variational Problems
Courant Institute of Mathematical Sciences
March 4, 1982

H. Hattori
The Partial Differential Equation $U_T+F(U)_x=-CU$
University of Kentucky
March 18, 1982