Semi-Annual Report

Grant No. NAG-1-242

RESEARCH IN COMPUTER SCIENCE

Submitted to:

National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia   23665

Attention: Dr. John N. Shoosmith
ACD, MS 125
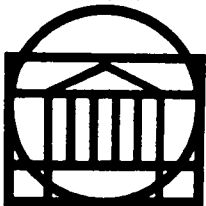
Submitted by:

James M. Ortega
Professor and Chairman

Report No. UVA/528209/AM86/108

January 1986

SCHOOL OF ENGINEERING AND

APPLIED SCIENCE

DEPARTMENT OF APPLIED MATHEMATICS

UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VIRGINIA 22901

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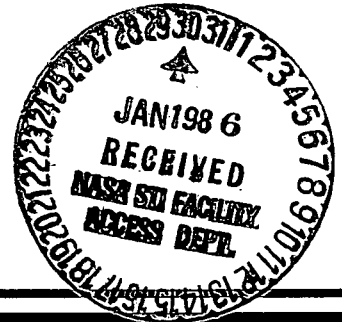
Submitted by:
James M. Ortega
Professor and Chairman

Department of Applied Mathematics
SCHOOL OF ENGINEERING AND APPLIED SCIENCE
UNIVERSITY OF VIRGINIA
CHARLOTTESVILLE, VIRGINIA

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This report summarizes work under NASA Grant NAG-1-242 for the period June 1,1985 to December 1, 1985. During this period, six graduate students were supported. The students, their area of research, Langley contact, University of Virginia advisor, and total period of support are given below.

Student	Area	Langley Contact	Advisor	Period
S. Brilliant	Software Engineering	E. Senn	J. Knight	6/1/83 – 8/31/85
A. Cleary	Concurrent Processing	J. Stroud	J. Ortega	6/1/85 – 8/31/85
S. Linde	Concurrent Processing	D. Dwoyer	J. Ortega	6/1/85 –
J. Marco	Artificial Intelligence	N. Orlando	W. Martin	5/28/84 –
E. Poole	Concurrent Processing	J. Lambiotte	J. Ortega	.6/1/83 – 8/31/85
C. Vaughan	Concurrent Processing	J. Stroud	J. Ortega	1/15/85 – 8/31/85

Of the above students, Cleary, Linde, Marco and Vaughan spent the summer at Langley Research Center. Brilliant and Poole, who had each spent two summers at Langley Research Center, continued their research at the University of Virginia. During the Fall, 1985 semester, Linde and Marco have been supported by this grant while the others have continued their research under other support: Brilliant, Cleary and Vaughan on other NASA grants, Poole on a Control Data Corporation Pacer Fellowship.

The degrees being pursued by these six people with the expected completion dates are given below.

Student	Degree	Expected Completion
S. Brilliant	Ph.D – Computer Science	Fall, 1986
A. Cleary	M.S. – Applied Mathematics	Summer, 1986
S. Linde	Ph.D – Applied Mathematics	1987
J. Marco	M.S. – .Computer Science	Spring, 1986
E. Poole	Ph.D – Applied Mathematics	Spring, 1986
C. Vaughan	Ph.D – Applied Mathematics	1987

Cleary and Marco are both planning to continue on to a Ph.D after completion of their master degrees.

We next give short summaries of the work performed during the reporting period.

Failure Probabilities in Multi-Version Software

Susan S. Brilliant, Ph.D. Candidate in Computer Science
John C. Knight, Associate Professor of Computer Science

Multi-version programming has been proposed as a method of incorporating fault tolerance into software. Multiple versions of a program are prepared independently and executed in parallel. Their outputs are collected and examined by a voter, and, if they are not identical, it is assumed that the majority is correct. The multi-version approach is being used in existing crucial systems, such as the Airbus Industrie A310 and Boeing 737-300 aircraft, and is being considered for others.

We have shown previously in a large-scale experiment that the assumption of independence of version failures in multi-version systems is *false*. The modeling of the reliability of a multi-version system becomes quite difficult when the assumption of independence cannot be made. The estimation of the software reliability depends upon the reliability of the individual versions *and* their interaction. This has been modeled, but little is known about how programs will fail in practical multi-version systems. In order to obtain some preliminary data, the results of the tests that had been run for the experimental evaluation of independence were used to determine how various multi-version systems would have behaved. In order to measure the failure probability that would be achieved by multiple-version systems built from this database of programs, the failure probabilities of all possible combinations of two and three versions were determined.

For the particular application that was programmed for this experiment, the reduction in the failure probability resulting from combining the programs into 3-version units was approximately a single order of magnitude. However, if the programs used in the experiment had failed independently, the reduction would have been at least *three* orders of magnitude. The use of a 2-version system increased the failure probability by approximately two orders of magnitude, but more that 99% of the errors that occurred were detected.

Gaussian Elimination on Parallel Computers

Andrew C. Cleary, Masters Candidate in Applied Mathematics
James M. Ortega, Professor of Applied Mathematics

This research is concerned with implementing Gaussian elimination on existing parallel architectures for use in the solving of large systems of linear equations. Gaussian elimination has been well studied in serial environments; however, the problem of efficiently implementing this algorithm on parallel computers is rather new. The computers being considered in this case are the Intel Hypercube, a system with a number of processors equal to a power of two arranged in a hypercube topology, and the Flex/32, a shared memory computer with approximately 20 processors (currently at NASA-LARC). The Flex/32 is not fully operational, and so to this date most of the work has been with a simulator for the hypercube. Work with a real hypercube is just beginning by remote access to Oak Ridge National Laboratories' hypercube.

A variety of versions of Gaussian elimination have been implemented on the hypercube simulator. Most of the work has been concerned with cases where partial pivoting is not required. Versions working under this assumption include versions with wrap mapping of rows and wrap mapping with columns; various forms of broadcast strategy; and rearrangement of the order of computations in order to more effectively mask the cost of communication between processors. Timing results have been made, and although they have provided useful insights, they are limited in that the simulator can only deal with problem sizes that are much smaller than the problems of interest. This problem will be overcome by using the real hypercube at ORNL.

Three Dimensional Poisson Solvers on Parallel/Vector Computers

Cassandra S. Linde, Ph.D. Candidate in Applied Mathematics
James M. Ortega, Professor of Applied Mathematics

A key portion of the algorithm for the numerical solution of the time dependent Navier-Stokes equations in three-space dimensions is the numerical solution of a Poisson-type equation. Finite difference discretizations of this equation yield in general a nonsymmetric matrix; however, a diagonal transformation results in a symmetric (and positive definite) matrix. We solve the transformed problem and then easily obtain a solution of the original problem. We are concerned with air flow over an airplane, and thus we consider as our region of interest a rectangular parallelopiped elongated in the x-direction. For now, Dirichlet boundary conditions are assumed.

During the past few months, preconditioned conjugate gradient with m steps of polynomial preconditioning has been implemented on the Cyber 205 at Langley Research Center to solve Poisson's equation on the unit cube with a constant right-hand side. A red-black ordering of the grid points and long vectors which included intermediate boundary values were used. Uniform spacing in all directions was considered, and storage of the matrix was not necessary.

With the introduction of variable spacing in the z-direction a different approach was indicated. Currently, the same iterative method is being implemented to solve a Poisson-type equation on our region of interest. Now, however, uniform spacing is used only in the x- and y-directions with spacing in the x-direction and not necessarily equal to spacing in the y-direction. A red-black coloring scheme is again applied and storage of the resulting matrix by diagonals is employed. Long vectors which include intermediate boundary values are not considered.

This work is being done in conjunction with D. Dwoyer and T. Zang of the Computational Methods Branch.

3.

Toward Automated Task Decomposition for Multiple Robot Arms: The Automatic Selection of End-effectors

Jerrold L. Marco, Masters Candidate in Computer Science
Worthy N. Martin, Assistant Professor of Computer Science

Most robots in use today are merely repeating a small set of pre-programmed motions to carry out a simple task in a highly constrained environment. Robots such as the space shuttle's Remote Manipulator System which operate in free, unconstrained environments require constant direction by a human operator. The ultimate goal of this research is to produce truly autonomous robots which will be capable of determining for themselves how to go about accomplishing tasks which they have been assigned.

One of the decisions that would have to be made by a computer controlling such a set of autonomous robots is what "hands" and tooling to use on the end of each robot arm available to it. The goal of this project is to show the applicability of artificial intelligence techniques to the problem by producing a computer program capable of making such decisions, given that the task at hand is known to it.

A set of satellite repair tasks has been chosen as the domain for the demonstration system. We envision multi-armed, orbiting robots with a variety of tools, grippers, and sensors available to them. A computer program is being designed to match tools to tasks, using concepts of semantic networks and frames. It will be implemented, and used to help prove the feasibility of such satellite repairing robots.

This work is being done in collaboration with Nancy Orlando of the Automation Technology Branch.

Multi-Color Incomplete Cholesky Conjugate Gradient Methods on the Cyber 205

Eugene L. Poole, Ph.D. Candidate in Applied Mathematics
James M. Ortega, Professor of Applied Mathematics

The incomplete Cholesky conjugate gradient (ICCG) method is an iterative method which can be applied to solve large, sparse matrix problems that often arise in scientific applications in engineering. We have demonstrated that with multi-color orderings and diagonal storage both the factorization and forward and back solves necessary to implement ICCG can be carried out with long vector operations. Of particular concern is the rate of convergence of the multi-color ICCG methods compared with the usual ICCG methods associated with the natural ordering for the model problems we are considering. The purpose of the current research is to extend and generalize the results already obtained from two different two dimensional model problems to three dimensional structural problems. We are currently considering a simplified model of a space platform. A program is running on the Cyber 205 which applies the multi-coloring strategy to this three dimensional model.

Parallel Implementation of Iterative Methods for Solving Linear Equations

Courtenay T. Vaughan, Ph.D Candidate in Applied Mathematics
James M. Ortega, Professor of Applied Mathematics

This project is currently involved in the implementation of iterative methods for solving linear equations on parallel computers. The computers which are being used are the Flex/32, a shared memory parallel computer with up to twenty processors, and the Intel hypercube, a parallel computer with 64 nodes (processors) arranged in a hypercube topology. The iterative methods will have to be modified in order to run efficiently in parallel. After the methods have been implemented on both machines, the results will be compared in order to compare the computers and try to determine their advantages and disadvantages.

The iterative methods which are being studied are Jacobi's method, SOR, conjugate gradient, and m step SSOR preconditioned conjugate gradient. The model problems being used are Poisson's equation on the unit square and a mixed derivative problem. After these methods have been compared for these model problems, the plane stress problem will be considered. All of these methods have been implemented on a simulator for the hypercube. These programs should transfer to the hypercube with a few modifications and this is being done currently. Due to problems with the Flex/32, only implementation on Jacobi's method has so far been attempted.

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UNIVERSITY OF VIRGINIA
School of Engineering and Applied Science

The University of Virginia's School of Engineering and Applied Science has an undergraduate enrollment of approximately 1,500 students with a graduate enrollment of approximately 500. There are 125 faculty members, a majority of whom conduct research in addition to teaching.

Research is a vital part of the educational program and interests parallel academic specialties. These range from the classical engineering disciplines of Chemical, Civil, Electrical, and Mechanical and Aerospace to newer, more specialized fields of Biomedical Engineering, Systems Engineering, Materials Science, Nuclear Engineering and Engineering Physics, Applied Mathematics and Computer Science. Within these disciplines there are well equipped laboratories for conducting highly specialized research. All departments offer the doctorate; Biomedical and Materials Science grant only graduate degrees. In addition, courses in the humanities are offered within the School.

The University of Virginia (which includes approximately 1,500 full-time faculty and a total full-time student enrollment of about 16,000), also offers professional degrees under the schools of Architecture, Law, Medicine, Nursing, Commerce, Business Administration, and Education. In addition, the College of Arts and Sciences houses departments of Mathematics, Physics, Chemistry and others relevant to the engineering research program. The School of Engineering and Applied Science is an integral part of this University community which provides opportunities for interdisciplinary work in pursuit of the basic goals of education, research, and public service.