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One of the most important computer architecture innovations to appear in the market place during the last ten years is parallel processing on a shared memory multicomputer. This report presents new algorithms for a variety of network models along with empirical analysis on both sequential and parallel computers. An empirical study on the AT and T KORBX system is also presented. This system uses eight processors each of which has vector capability.					
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AN ~~ANNUAL~~ TECHNICAL REPORT TO

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

by

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for

Optimization Algorithms for New Computer Architectures with Application to Routing and Scheduling (Year 3)

October 1, 1990

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I. STATEMENT OF WORK

Many Air Force applications demand computer hardware several orders of magnitude faster than the fastest machines available. Computer designers (including Semour Cray) have turned to parallelism as one of the more promising avenues for increased computational speed. Parallelism shifts some or the burden for increased speed from the hardware to the software engineer. Very powerful hardware (in terms of millions of floating point operations per second) can be built using many low cost standard chips, all designed to operate in parallel. Our research program objective is to develop and empirically test new parallel algorithms and software for a wide variety of optimization problems. The problems studied this past year include the shortest path problem, the assignment problem, the semi-assignment problem, the transportation problem, and the generalized network problem. Algorithms for all of these models have been developed and empirically tested on a variety of computers. In addition, we worked with the Military Airlift Command to test the AT&T KORBX system located at Scott Air Force Base.



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II. PERSONNEL

Faculty

Jeffery L. Kennington

Richard V. Helgason

Ph.D. Students

Zhiming Wang

Ph.D. received May 1990

**Dissertation Title: The Shortest Augmenting Path Algorithm for
Bipartite Network Problems**

Douglas Stewart

Betty Hickman

Nandagopal Venugopal

III. PUBLICATIONS

The following is a list of the papers completed during the last year, an executive summary of the paper, and the publication status. These seven papers also appear in this document.

Title

An Empirical Evaluation of the KORBX Algorithms for Military Airlift Applications

Technical Report 89-OR-06

Revised May 1989

Authors

Major W. Carolan, Major J. Hill, J. Kennington, Second Lieutenant S. Niemi, and Captain S. Wichman

Executive Summary

This report presents an empirical analysis of the four algorithms which are implemented in the AT&T KORBX system which is being used by the Military Airlift Command at Scott Air Force Base. A set of twelve large MAC models were run with all four algorithms (primal, dual, primal-dual, and power series) and compared where possible with MPSX.

Publication Status

Published in Operations Research March 1990.

Title

Performance Characteristics of the Jacobi and the Gauss-Siedel Versions of the Auction Algorithm on the Alliant FX/8

Technical Report 89-CSE-33

Revised October 1989

Authors

D. Kempka, J. Kennington, and H. Zaki

Executive Summary

This report presents an empirical analysis comparing the Jacobi and Gauss-Siedel versions of Bertsekas' auction algorithm. The tests were run on an Alliant FX/8 located at the Argonne National Laboratory. The Jacobi version yielded the best speedups (up to about nine) and was less sensitive to changes in the cost range. Both algorithms ran rather well in the vector-concurrent mode and we concluded that the auction algorithm is well suited for parallel implementation.

Publication Status

This paper has been submitted for publication and is currently under review.

Title

Computational Comparison of Sequential and Parallel Algorithms for the One-To-One Shortest-Path Problem

Technical Report 89-CSE-32

November 1989

Authors

R. V. Helgason, J. L. Kennington, and B. D. Stewart

Executive Summary

The problem of finding the shortest path between a designated pair of nodes in a graph is a fundamental problem in operations research which also serves as a building block for other algorithms such as the out-of-kilter algorithm and the shortest augmenting path algorithm. The classical Dijkstra algorithm begins at one of the designated nodes and fans out from this node until the other designated node becomes a member of the labeled set. In this investigation we empirically demonstrate that a better algorithm is obtained by a procedure that begins at both designated nodes and fans out in both directions. This is accomplished mathematically and in parallel by building trees rooted at the two designated nodes. The algorithm stops when any node appears in both trees.

Publication Status

This paper has been submitted for publication and is currently under review.

Title

Generalized Networks: Parallel Algorithms and an Empirical Analysis

Technical Report 90-CSE-1

January 1990

Authors

J. Kennington, R. Clark, R. Meyer, and M. Ramamurti

Executive Summary

The generalized network problem in its most general form is a special case of a linear program in which every column of the constraint matrix has at most two nonzero elements. Special cases of this model include the flow with gains problem, the minimal cost network flow problem, the transportation problem, the assignment problem, the maximal flow problem, and the shortest path problem. In this study we empirically demonstrate that specialized software for this model is an order of magnitude faster than MPSX. This algorithm was parallelized and speedups up to eleven were achieved on a Sequent Symmetry S81 multicomputer using nineteen processors.

Publication Status

This paper has been submitted for publication and is currently under review.

Title

The Shortest Augmenting Path Algorithm for the Transportation Problem

Technical Report 90-CSE-10

February 1990

Authors

J. Kennington and Z. Wang

Executive Summary

This paper presents a new algorithm for the transportation problem along with an empirical analysis of the software implementation of this algorithm. The algorithm will achieve an optimal solution in $O(Umn)$ time where U is the total supply, m is the number of sources, and n is the number of destinations. When U is small, the software implementation of this algorithm is the fastest that we have seen.

Publication Status

This paper has been submitted for publication and is currently under review.

Title

A Shortest Augmenting Path Algorithm for the Semi-Assignment Problem

Technical Report 89-CSE-34

Revised July 1990

Authors

J. Kennington and Z. Wang

Executive Summary

This paper presents a new algorithm for the semi-assignment problem. The new algorithm has the best run time bound for this problem and its software implementation performs better than all competing software.

Publication Status

This paper has been accepted for publication in Operations Research.

Title

SEMI User's Guide

Technical Report 90-CSF -20

July 1990

Authors

J. Kennington and Z. Wang

Executive Summary

This report describes the use of a FORTRAN code for sparse semi-assignment problems. This code is based on the algorithm presented in Technical paper 89-CSE-34. We share our software with others and this User's Guide is a manual for the software.

Publication Status

This report will not be submitted for publication. It is distributed to those who ask for a copy of our semi-assignment software.

IV. PRESENTATIONS

ORSA/TIMS Joint National Meeting

New York City

October 16-18, 1989

1. Network's Decomposition for Solving the s-t Shortest Path Problem
D. Stewart and R. Helgason
2. Graph Partitioning Via Sparsest Cuts: Test Problem Generation and a Solution Scheme
K. Thiagarajan, P. Bartholomew, R. Helgason, and D. Matula
3. An Empirical Evaluation of the KORBX Algorithms for Military Applications
J. Kennington, W. Carolan, J. Hill, and S. Wichmann
4. The Shortest Augmenting Path Algorithm for the Transportation Problem
Z. Wang

TIMS/ORSA Joint National Meeting

Las Vegas

May 7-9, 1990

1. Solving the Multicommodity Network Flow Problem on Parallel Computers
H. Zaki and R. Helgason
2. Computational Comparison of Sequential and Parallel Bi-Directional Algorithms for Solving the s-t Shortest Path Problem
D. Stewart and R. Helgason
3. A Shortest Augmenting Path Algorithm for the Semi-Assignment Problem
Z. Wang and J. Kennington