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Final Report on Contract N00014-89-J-1528 (1/1/89-5/31/90)

1. Summary

The tasks accomplished as of May 31, 1990 are:

Title

A. Completion of a monograph entitled *"DECOMP: an Implementation of Dantzig-Wolfe Decomposition for Linear Programming."*

A large part of our computational work is based on DECOMP, a Fortran implementation of the Dantzig-Wolfe decomposition algorithm for block-angular linear programs. This code has evolved over a period of fifteen years into a robust and relatively portable experimental tool for large-scale mathematical programming. While it has been distributed by the PI to many researchers worldwide, comprehensive documentation was not available. This task resulted in a complete tutorial, user's guide and programmer's manual in the form of a 206-page monograph [5] published in the Springer-Verlag Lecture Notes Series in Economics and Mathematical Systems.

B. Implementation of DECUBE, a linear programming decomposition code in Fortran on an Intel iPSC/2 Hypercube computer with 64 processors.

The iPSC/2-d6 consists of 64 Intel 80386 processors connected in a six-dimensional hypercube topology. It is a superb example of the cost-effectiveness of multiprocessors and is becoming standard equipment in many advanced computing centers. Our initial experience [3] demonstrated that DECUBE can outperform state-of-the-art commercial LP software (MPSX/370 V2) on mainframe super-computers (IBM 3090) that cost 20 to 30 times more than the iPSC/2.

C. Analysis and empirical study of computational strategies and the dynamics of information in parallel decomposition.

Results were presented at the ORSA/TIMS Joint National Meeting in Vancouver, B.C., Canada in May 1989. The implications of the results are described in a technical report [4] entitled "Dynamics of Information in Distributed Decision Systems."

D. The multistage, multiproduct material requirements planning problem with capacity constraints.

Results were presented at the ORSA/TIMS Joint National Meeting in New York, NY, in October 1989. We showed previously that the basis in a class of linear programs arising from material requirements planning can be triangularized. This allows for efficient adaptation of the Simplex Method similar to those for network problems. It also suggests that for finite-loading (i.e. capacitated) MRP, a decomposition approach exploiting both subproblem structure and parallel processing can be effective for handling complex problems in multiproduct, multistage, multiperiod production systems. The initial results (reported in [3] and [6]) of using DECUBE on this class of problems are very promising. Examples with up to 30,000 constraints were solved under 15 minutes. A commercial LP code took over 50 minutes on a mainframe supercomputer costing 20 to 30 times more than the hypercube. We believe that this development will have substantial impact on the application of optimization to operations management.

E. The dynamic traffic assignment problem.

Initial results on the application of a nested decomposition algorithm using parallel computation were presented at the Joint USA-Italy Workshop on Urban Traffic Networks in Capri, Italy in

June 1989. Previously, the PI has shown that a class of non-linear, non-convex dynamic network flow problems can be solved as a sequence of linear programs. The LP's have the staircase structure typical of time-phased problems. Initial experience of applying a nested decomposition algorithm using parallel computation was promising [2].

F. Stochastic linear programming using importance sampling and parallel computation.

The two-stage stochastic LP with an L-shaped deterministic equivalent is solved by Bender's decomposition using a Monte Carlo (importance) sampling technique to approximate the random distribution. Parallel processing of the sampled subproblems is implemented on a 64-node hypercube computer. Preliminary results in collaboration with Dr. Gerd Infanger of the Technical University of Vienna and Prof. George Dantzig of Stanford University were presented at ORSA/TIMS Joint National Meeting in Las Vegas, NV, in May 1990.

2. Publications and Reports under Contract N00014-89-J-1528

[1] Ho, J.K., "Nonprocedural implementation of mathematical programming algorithms," in R. Sharda (ed.), *Impact of Recent Advances in Computer Science on Operations Research*, North Holland, New York (1989) 226-237.

[2] J.K. Ho, "Solving the dynamic traffic assignment problem on a hypercube computer" (to appear in *TRANSPORTATION RESEARCH*, 1990)

[3] J.K. Ho and S.K. Gnanendran, "Distributed decompostion of block-angular linear programs on a hypercube computer" (submitted to *MATHEMATICAL PROGRAMMING*).

[4] Ho, J.K., and T.C. Lee, "Dynamics of information in distributed decision systems" Technical Report, Unversity of Tennessee, March, 1989.

[5] Ho, J.K. and R. Sundarraj, *DECOMP: an Implementation of Dantzig-Wolfe Decomposition for Linear Programming* , Springer-Verlag Lecture Notes Series on Economics and Mathematical Systems, No. 338, New York, 1989.

[6] S.K. Gnanendran, "Resource-constrained material requirements planning using parallel linear programming", Doctoral dissertation, University of Tennessee, 1989.