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RESEARCH ON INFEASIBLE INTERIOR-POINT
ALGORITHMS FOR LINEAR AND
NONLINEAR PROGRAMMING

Final Technical Report
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1 Overview

The current project is a renewal of the PI's previous projects supported by the Department of Energy. The original funding period for this project was from August 15, 1995 to August 14, 1996. The expiration date of the project was extended at no cost to August 14, 1997 in order to ensure a adequate completion of the original scope of work within the available funds. During this extended project period, the PI moved from the University of Maryland Baltimore County to Rice University.

The primary objective of the project was to bring a successful conclusion to an effort of transferring years of research into a freely available software package that are more accessible and user-friendly than then existing technologies in the field. Another objective of the project was to facilitate the transition of the PI's research concentrations to other areas of practical importance; in particular, to the area of semidefinite programming where interior-point methodology has proven to be most promising.

Both the objectives have been successfully accomplished. The software package LIPSOL, a centerpiece of the project, has recently been licensed to The MathWorks Inc. by the University of Maryland Baltimore County for planned incorporation into Matlab as the linear-program solver of Matlab. The PI has also made a number of contributions to the on-going research activities on semidefinite programming and other areas.

2 Summary of Completed Work

2.1 Further Development of LIPSOL

LIPSOL is a software package for solving linear programming problems by infeasible primal-dual interior-point methods. The code is written in Matlab, a widely used scientific and engineering computing system, and utilizes some existing Fortran programs, through Matlab's external interface, to carry out computation-intensive tasks.

We have completed most of the enhancements to LIPSOL as proposed in the renewal proposal. These enhancements include implementing techniques to deal with dense columns, incorporating a new version of ORNL Sparse Cholesky package and writing a user's guide. Most recently, we released LIPSOL version 0.40 that is compatible with the new Matlab version 5.

Two technical reports about the development of LIPSOL have been written during the project period. The first one is a User's Manual for the LIPSOL package, and the second a description of the algorithm and implementation employed in the LIPSOL package, as well as extensive numerical-testing results. See the Publication List.

LIPSOL has been widely used by researchers in many countries. During a recent conference (the 16th International Symposium on Mathematical Programming), I was told by several researchers from different countries that they have used LIPSOL in their research. At Rice University, a number of Ph.D. students have used or are currently using LIPSOL in their dissertation research.

As a final indication of its success, LIPSOL has been licensed to The MathWorks Inc., the maker of the Matlab system, through the Office of Technology Development at University of Maryland Baltimore County (the PI's former home institution until August, 1996). LIPSOL is expected to be modified and incorporated into the Matlab system as its linear program solver, while LIPSOL is still free to the public and will remain so in the future.

2.2 Semidefinite Programming and Other Research

Semidefinite programming is a relatively new area where interior-point methods have been found to be most effective. Semidefinite programming has applications in eigenvalue optimization, system and control theory, statistics and combinatorial optimization. The PI started doing research on semidefinite programming in the project period.

The PI obtained a number of new results on semidefinite programming as given in the two papers listed in the Publication List. In the first paper, we gave a concise derivation of some key equalities and inequalities and used these tools to extend for the first time a long-step primal-dual interior-point algorithm from linear programming to semidefinite programming. In the second paper, we analyzed a class of long-step primal-dual interior-point algorithms in a unified analysis and obtained polynomial complexity results. Our results also give indications as to which search directions are likely to be more efficient from a theoretical point of view.

The PI and his doctoral student Detong Zhang have also completed an investigation on constructing interior-point path-following algorithms for some non-monotone linear complementarity problems. For these problems, the

existence of interior-point homotopy paths were previously unknown. We proposed a new homotopy and established the existence of paths for several class of non-monotone linear complementarity problems. Our results can serve as a theoretical basis for the construction of interior-point path-following algorithms.

2.3 Graduate Education

A doctoral student, Detong Zhang, of the PI has completed his degree during the period of the project. He was partly supported by the project and participated in some aspects of the project. He is currently employed by a computer software company.

3 List of Publications

The following list contains the papers authored or co-authored by the PI and completed in the current project period.

1. Solving large-scale linear programs by interior-point methods Under the MATLAB Environment, 1996. To appear in *Optimization Methods and Software*.
2. User's Guide to LIPSOL – Linear-programming Interior Point Solvers. Technical Report TR95-19, Dept. of Math/Stat, University of Maryland Baltimore County, Baltimore, MD 21228, USA, 1995.
3. On extending some primal-dual interior-point algorithms from linear programming to semidefinite programming, 1995. To appear in *SIAM Journal on Optimization*.
4. A unified analysis for a class of path-following primal-dual interior-point algorithms for semidefinite programming (with Monteiro), 1996. To appear in *Mathematical Programming*.
5. On constructing interior-point path-following methods for certain semi-monotone linear complementarity problems (with D. Zhang). Technical Report TR97-19, Department of Computational and Applied Mathematics, Rice University, Houston, TX 77005. 1997. Submitted to *Computational Optimization and Applications*.