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18. key words

Nonlinear optimization, nonlinear equations, nonlinear least squares, inaccurate function values, nonlinear constraints, conjugate direction methods, Nelder-Mead simplex algorithm, nonlinear least squares, trust region algorithms, multi-objective nonlinear optimization, parameter identification, the Karmarkar linear programming algorithm.

19. Abstract

This grant provided support to 10 graduate students. Of these, 7 have received their Ph.D.'s and another will defend her thesis before October 1, 1989. Three of these students are female US citizens. With so many graduate students involved, the research pursued has necessarily been very broad within optimization. The most exciting accomplishment is a very robust implementation of a new trust region approach to global convergence for nonlinear programming problems. The proposal for continuing this work is centered around applying this algorithm to the parallel solution of parameter identification or inverse problem for ordinary differential equations. Other work is a variant of the Kamarkar linear programming algorithm that could be of great practical significance if currently proposed extensions to nonlinear programming pan out. A unified convergence analysis for the many variants of the conjugate gradient method, a parallel direct search optimization algorithm and attendant convergence analysis, a convergence analysis for a nonsmooth trust-region method, a convergence analysis for trust-region methods for nonlinear programming, and a novel use of interactive computer graphics to obtain user preferences in multi-objective optimization. Also, the PI with Professor Schnabel of Boulder completed an invited survey paper for the North Holland Handbook on Optimization.

Technical Summary

Outstanding progress was made on several topics in numerical optimization. Most noteworthy is that a new nonlinear programming algorithm has been developed for inequality constraints. So far it has only been implemented for equality constraints. If the inequality constrained case works as well as the current implementation, then this is a truly major accomplishment.

John Dennis, Richard Tapia, J. Martinez (of UNICAMP Brasil), Maria Celis (of Ardent Computers), and Karen Williamson are preparing a paper describing an interesting new method for nonlinear programming. This method uses some ideas developed for unconstrained optimization by Byrd, Schnabel, and Shultz and extends them into a new trust-region method that performs much better than sequential quadratic programming far from the solution. The algorithm also has the big advantages that it is easily able to deal with iterates with dependent constraint gradients and inconsistent linearized constraints, as well as with negative curvature directions for the Lagrangian. M. El-Alem completed his Ph.D. thesis giving a satisfying global convergence theorem for this algorithm. Dennis and Cristina Maciel have begun a project to extend this algorithm to large-scale nonlinear programming. Karen Williamson will defend her Ph.D. thesis on an analysis and implementation of the algorithm during September 1989. Ms. Williamson's implementation appears to be unsurpassed by any of the current SQP codes in robustness. Since it is based on Newton type methods, it is more difficult to compare efficiency, but it also appears to be competitive in that regard.

Dennis and Karen Williamson have working code for ODE parameter determination by initial value methods. However, the algorithm we are going to implement on the Sequent this winter is much more promising. Our new algorithm is based on the new algorithm for nonlinear programming, and the differential equation is viewed as an equality constraint to the nonlinear least squares problem. As a result of using parallel shooting boundary value techniques, the new algorithm offers many opportunities to exploit parallelism and gain efficiency by combining the optimization algorithm with the constraint and objective function evaluation.

Virginia Torczon and John Dennis have developed and analyzed a parallel version of the Nelder-Mead simplex algorithm. A Sequent implementation is much more robust than the Nelder-Mead algorithm, and for more than about 5 variables, it is also more efficient. A very interesting aspect of this work is that no one has ever been able to prove convergence of the sequential algorithm.

Ms Torczon's global convergence proof for the parallel algorithm, which formed the heart of the theoretical portion of her Ph.D. thesis, does not work for the sequential algorithm, but it does work for a parallel version of the Hooke and Jeeves algorithm as well. In the report for last year, we described a whole class of parallel Nelder-Mead variants. The algorithm we have been able to analyze is the 'most' parallel of the class.

Some other accomplishments of less import are a convergence theory for non-smooth trust region methods, and a new Karmarkar style algorithm for linear programming. The latter may turn out to be quite important because of some current work on extending it to nonlinear programming.

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7. (with Sheng Songbai and Phuong Vu) A Memoryless Augmented Gauss-Newton Method for Nonlinear Least Squares, *Journal of Computational Mathematics*, 6 (1988),pp.355-375.

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9. (with R. B. Schnabel) A View of Unconstrained Optimization, invited paper in *Optimization, Handbooks in Operations Research and Management Science, Vol 1.*, edited by G.L. Nemhauser, A.H.G. Rinnooy Kan, and M.J. Todd, North Holland, Amsterdam, pp.1-72.

10. (with M.R. Celis, J.M. Martínez, R.A. Tapia, K.A. Williamson) An Algorithm Based on a Convenient Trust-Region Subproblem for Nonlinear Programming, in preparation.