A strategy has been developed for the distribution of the constraint of large linear programs among parallel processors. New parallel algorithms for multi-commodity flows problems have been developed.
COMPUTER SCIENCES DEPARTMENT
University of Wisconsin-Madison

CENTER FOR PARALLEL OPTIMIZATION

Final Report for the Period
June 1, 1989 - September 30, 1993
Final Report

for the Period

June 1, 1989 - September 30, 1993
1. Period 1

June 1, 1989 - May 31, 1990
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INTRODUCTION & SUMMARY

The Center for Parallel Optimization (CPO) was established June 1, 1989 with a grant from the Air Force Office of Scientific Research. Its primary purpose is to provide an appropriate environment, both physically and intellectually, for the conception, development and implementation of computational algorithms for the parallel solution of optimization and related problems. The CPO shares the facilities and services of both the Computer Sciences Department and the Center for the Mathematical Sciences. Its staff is made up of the Principal Investigators: Professors Olvi L. Mangasarian and Robert R. Meyer, and the Co-Investigators: Visiting Assistant Professor Renato De Leone and Assistant Professor Michael C. Ferris. This report summarizes the activities of the CPO during its first year of existence. These activities, described in the following sections, are as follows.

1. Research Narrative. Each of the four investigators describes informally his research achievements during the past year.

2. CPO Reports & Papers. A listing of 18 papers and reports written in the past year by the investigators and their Ph.D. students is given.

3. Talks by CPO Staff. Thirty four talks in the U.S. and abroad were given by the investigators and their Ph.D. students, most of them by invitation.

4. CPO Ph.D. Students. Ten Ph.D. graduate students were supported by the CPO faculty with CPO, NSF and UW funds.

5. CPO Visitors & Speakers. A total of 28 talks were given at Madison under the sponsorships of the CPO. Of these 13 were by outside visitors, both U.S. and foreign. These visitors spent varying periods of time at the CPO, between a minimum of 3 days to a maximum of 6 months. Some visitors came with their own funds, others were supported by the CPO.
1. RESEARCH NARRATIVE

R. De Leone

My research has resulted in new convergence conditions for partially asynchronous successive overrelaxation algorithms for linear complementarity problems. These conditions allows more efficient exploitation of parallel architectures.

I have implemented a fast parallel version of Lemke’s algorithm on the Intel iPSC/2 which takes advantage of the vector capability of the machine and achieves near-linear speed-up for large-scale linear complementarity problems.

I have solved large multicommodity network optimization problems based on the Military Airlift Command PDS (Patient Distribution Model). A problem with 50,000 constraints and more than 150,000 variables (PDS-30) was solved in less than 17 hours on a DECSTATION 3100 with an absolute error accuracy of $0.1 \times 10^{-5}$ in constraint satisfaction.

With Mangasarian, I have developed a strategy for distributing the constraints of large linear programs among parallel processors that will allow the solution of very large problems. We are currently testing the effectiveness of the method.

M. C. Ferris

My research interests are concerned with several current problems in mathematical programming, with particular emphasis on the theory of nonlinear programming and the implementation of efficient algorithms, both on serial and parallel architectures. The long-range goal of my research is to develop and implement stable algorithms to find global solutions of nonlinear programs and investigate the usefulness of probabilistic search methods. In order to achieve this, I have been investigating three main ideas which I believe will produce efficient computational methods.

The first of these are the so-called genetic algorithms, which I have applied to some general optimization problems. The particular emphasis of the research is to determine what factors affect a parallel implementation of the method. I have isolated several features of these approaches which makes it attractive for such implementation, including local neighborhoods. These ideas significantly reduce communication and synchronization penalties. A prototype asynchronous method based on these ideas is currently being tested.

I have been investigating the use of nonmonotone linesearch procedures in nonlinear programming codes. The use of nonmonotone linesearches enables steplengths of one to be taken much more frequently and in initial trials has led to considerable improvements over the traditional damping procedures. I am looking at ways of generalizing variants of Newton’s method in order to effect the solution of nonsmooth equations. These are of particular interest for nonlinear complementarity problems, since there are several ways of formulating such problems as nonsmooth equations. Although the utility of parallelism is not so
apparent here, I feel that it can be employed sensibly in the solution of projection problems and for direction finding, and current work is being carried out to implement parallel equation solvers for use in these codes.

In recent work with Burke and Mangasarian, we have identified a property of a given problem, namely a weak sharp minimum, which results in a finite termination property by means of a simple modifying process involving the solution of a single linear program. This property has been investigated in relation to linear complementarity problems and nondegeneracy, with several existence results and equivalences established.

O. L. Mangasarian

Together with Dr. William H. Wolberg of the Department of Surgery at University of Wisconsin Hospitals and my Ph.D. student Rudy Setiono, I have used linear programming to develop software for the diagnosis of breast cancer. The software has been in use at the U.W. Hospitals for over a year with great success. Originally trained on 369 samples, the software diagnosed all of 70 subsequent cases correctly except one. At that time it was retrained and since then it has correctly classified all 31 subsequent cases.

With my student Kristin Bennett we have shown that a linear programming procedure for pattern recognition can be viewed as a neural network with a specific topology. The linear programming approach, when tested on medical diagnosis problems, and certain other problems outperforms the standard Back Propagation Algorithm of neural networks in speed of training, in determining the minimal number of hidden units, and in correctly classifying the training set. On testing sets it does as well or better than Back Propagation.

Matrix splitting is an effective way for parallelizing the solution of very large linear programs and nonlinear programs. Recently I established iterate convergence of a class of matrix splittings where the subproblems are solved inexactly. This approach when combined with a constraint distribution procedure that I have been developing together with De Leone, may yield a practical way of solving extremely large problems that cannot be handled by existing computer technology.

R. R. Meyer

My research under this grant has emphasized parallel algorithms for large-scale network optimization problems. Problems of this class arise in a variety of Air Force logistical applications.

In the area of single-commodity pure and generalized networks, my research with my Ph.D. student Rob Clark (now working for IBM in mathematical programming software development) led to the development of parallel versions of the network simplex method on the Sequent Symmetry S81 shared-memory multiprocessor. We collaborated with Jeff Kennington of SMU in testing some of these parallel algorithms in order to have a broad range of test problems and algorithms for comparison purposes. The codes developed under the CPO
grant were shown to be significantly faster than the well-known IBM code MPSX and other leading network flow codes. Particularly good speedups were obtained on very large generalized network flow problems of over 1 million variables, which were solved on the Sequent in just over 8 minutes. The multi-processor approach developed in this research for network flow problems also has promise for general linear programming problems, since it emphasizes the parallelism inherent in the simplex pricing operation.

A second area of my research in parallel algorithms for network flows has been multi-commodity flows, where I have developed a decomposition approach combining a barrier function technique (associated with interior point methods) with a coordination step related to the well-known Dantzig-Wolfe method. This method has been proved to be convergent under some very general conditions, and has been demonstrated to be very effective in solving very large versions of the Air Force Patient Distribution System models. In fact, by using this algorithm we have been able to solve, with my Ph.D. students Gary Schultz and Jonathan Yackel, problems of this class that are much larger than those reported elsewhere. I am now investigating generalizations of this approach that are related to simplicial decomposition, and offer the possibility of accelerating convergence through the combination of multiple previous updates.
2. CPO REPORTS & PAPERS


3. TALKS BY CPO STAFF

R. De Leone


M. C. Ferris


O. L. Mangasarian


R. R. Meyer


4. CPO PH.D. STUDENTS
SUPPORTED BY AFOSR, NSF & UW GRANTS

1. Kristin Bennett (Mangasarian)
2. Menglin Cao (Ferris)
3. Rob Clark (Meyer; Ph.D. granted 8/89)
4. Terence Ow (De Leone; until 12/89)
5. Stephen Palzewicz (De Leone)
6. Jun Ren (Mangasarian)
7. Gary Schultz (Meyer)
8. Rudy Setiono (Mangasarian)
9. Robert Welch (Ferris)
10. Jonathan Yackel (Meyer)
5. CPO VISITORS AND SPEAKERS


Andrew Philpott, University of Auckland, New Zealand, "Rostering staff using assignment algorithms", January 18, 1990.

Michael Ferris, University of Wisconsin, Madison, "Trust regions and line searches", February 1, 1990.

Renato De Leone, University of Wisconsin, Madison, "Parallel implementation of Lemke's algorithm on the hypercube", February 8, 1990.


Yannis E. Ioannidis, University of Wisconsin, Madison, "Randomized algorithms for query optimization", March 1, 1990.


Danny Ralph, University of Wisconsin, Madison, "Nonsmooth Newton's method in nonlinear programming", April 12, 1990.


Xiangqian Wu, University of Wisconsin, Madison, "Optimized diagnostic scheme for parameterizing fractional cloud cover in numerical weather prediction model", May 3, 1990.

2. Period 2

June 1, 1990 - September 30, 1991
INTRODUCTION & SUMMARY

This report describes the continuing research at the Center for Parallel Optimization (CPO). The center was established June 1, 1989 with a grant from the Air Force Office of Scientific Research. Its primary purpose is to provide an appropriate environment, both physically and intellectually, for the conception, development and implementation of computational algorithms for the parallel solution of optimization and related problems. The CPO shares the facilities and services of both the Computer Sciences Department and the Center for the Mathematical Sciences. Its staff is made up of the Principal Investigators: Professors Olvi L. Mangasarian and Robert R. Meyer, and the Investigators: Visiting Assistant Professor Renato De Leone and Assistant Professor Michael C. Ferris. This report summarizes the continuing activities of the CPO during the 16-month period of June 1, 1990 to September 30, 1991. Their activities, described in the following sections, are as follows.

1. Research Narrative. Each of the four investigators describes informally his research achievements during the 16 months covered by this report.

2. CPO Reports & Papers. A listing of 35 papers and reports written in the 16 months covered by this report by the investigators and their Ph.D. students is given.

3. Talks by CPO Staff. Forty talks in the U.S. and abroad were given by the investigators and their Ph.D. students, most of them by invitation.

4. CPO Ph.D. Students. Twelve Ph.D. graduate students were supported by the CPO faculty with CPO, NSF and UW funds.

5. Symposium on Parallel Optimization 2. This 3-day symposium was held in Madison July 23-25, 1990, with 20 invited speakers. Refereed proceedings of the symposium have appeared as Volume 1, Number 4 of the SIAM Journal on Optimization in November of 1991.

6. CPO Visitors & Speakers. Over 35 people visited the Center during the 16 months covered by this report. These visitors spent varying periods of time at the CPO, a minimum of 3 days to a maximum of 6 months. Some visitors came with their own funds; others were supported by the CPO.

7. Acquisition of CM-5 supercomputer. All four CPO faculty members participated in a 1990 equipment proposal to NSF for new parallel computers for the Computer Sciences Department. This proposal was funded in 1991 at the level of $2,000,000 plus additional matching funds from the College of Letters and Science and the Graduate School. The first supercomputer acquired with this funding was a Thinking Machines Corporation CM-5 with 64 processors, installed in September, 1991.
1. RESEARCH NARRATIVE

R. De Leone

My research under this grant has focused on the following areas: parallel solution of large-scale linear and quadratic programs, parallel solution of 0-1 knapsack problems and integer programming formulation of problems in high-level synthesis for VLSI design.

In the area of parallel solution of large scale optimization problems I focused my attention on two important classes of problems: multicommodity network optimization problems and quadratic programs with simple bounds. Using successive overrelaxation (SOR) algorithms I was able to solve the Military Airlift Command PDS (Patient Distribution Model) problems. The largest problem solved in this class (PDS-40) has more than 60,000 constraints and 210,000 variables. On a IBM RISC 6000 POWERstation, a solution was obtained in less than 3.5 hours with seven-figure accuracy in constraint satisfaction.

Extremely large quadratic programs with simple bounds were also solved by using SOR techniques on two massively parallel supercomputers: the Connection machine CM-2 and the MasPar MP-1. On the 16,384-processor MasPar MP-1 a problem with more than 9,000,000 variables was solved in less than 2 hours. By comparison, the largest problem in this class solved by Karmarkar-type interior point algorithms involved less than 500,000 variables and required more than 2.5 hours on a large IBM mainframe.

In the area of parallel solution of 0-1 knapsack problems, I concentrated on massively parallel algorithms based on dynamic programming. Problems with as many 100,000 variables were solved and near-linear speedups were achieved.

Finally, in the area of VLSI design, we formulated the binding and allocation process for high-level synthesis as a 0-1 integer program. As far as we know this is the first attempt to provide a complete mathematical formulation for this problem. We successfully tested our approach on small problems. However, the number of variables and constraints quickly grows. We plan to use parallel branch-and-bound algorithms as well as parallel heuristic techniques to solve larger problems.

M. C. Ferris

My research under this grant has focused on the following two areas: parallel constraint distribution for nonlinear programs and genetic algorithms.

In my work on parallel constraint distribution with Mangasarian, we showed how to split the constraints of a nonlinear program among several processors and achieve fast practical convergence. A convergence theory was developed from operator splitting theory and an implementation of the method showed that this technique produced a solution to a given problem in small numbers of iterations independent of the number of processors used. To our knowledge, this is the first time that such a result has been claimed and has led to renewed
interest in such techniques.

I have isolated the important properties of genetic algorithms and the framework in which such methods should be used. The use of local neighborhoods in these methods on an Intel hypercube enabled me to significantly reduce communication times without degrading the solutions at all. Particular applications have been investigated, namely assembly line balancing and database query optimization.

In other related work, I have been investigating the use of path search techniques for general variational inequalities. In order to produce a practical code for such problems, I have been developing a code to run within the GAMS modelling environment. This will enable many economists and engineers to formulate and solve their models in a complementarity framework. As a constituent part of this work, I have developed a pivotal code to solve affine variational inequalities which is currently being used at Cornell University and the University of Washington.

O. L. Mangasarian

My research has focused on three areas: mathematical programming and neural networks, parallel optimization and error bounds.

In the neural network application area, our working neural diagnostic program at University of Wisconsin Hospitals has continued to diagnose breast cancer at a cumulative correctness rate of 98%. We have come up with practical, computational and theoretical enhancements that have improved the generalization capability of our diagnostic neural net. We have also solved a long-standing problem of approximately separating two disjoint point sets in n-dimensional real space with intersecting convex hulls by reducing it to a single linear program which is guaranteed to solve the problem without any modification.

In parallel optimization together with Ferris we have come up with an efficient procedure for distributing constraints among parallel processors in order to reduce problem size and introduce parallelism into our algorithm. Preliminary results are very encouraging. Along those lines I have also come up with an inexact matrix splitting method for solving the symmetric linear complementarity problem. This is a fundamental problem which underlies many optimization problems, including linear programming. The proposed algorithm is capable of solving extremely large problems both on serial and parallel processors.

In my ongoing research on error bounds, I have been interested in obtaining new and more effective bounds which allow us to gauge how good is an arbitrary point, for example one generated by any algorithm, by bounding its distance from the solution set. Such bounds are essential for terminating algorithms. They are also essential for designing fast algorithms. We have obtained a number of such bounds for various classes of optimization problems, some of which may lead to new and more powerful methods of solution.
My research under this grant has emphasized parallel algorithms for large-scale network optimization problems and optimal methods for allocating data among parallel processors. Problems of the first type arise in a variety of Air Force logistical applications, and the research in the second area was motivated by a large-scale database application.

Under my direction, Gary Schultz, a research assistant supported by the CPO grant, recently completed his Ph.D. thesis in parallel algorithms for multi-commodity flows and other block-structured problems. This research led to the development of a decomposition approach combining a barrier function technique (associated with interior point methods) with a coordination step based on the solution of a low-dimensional nonlinear optimization problem. Novel aspects include generation of a feasible solution in a finite number of iterations (under very mild assumptions on the structure of the feasible set) and proof of convergence of asynchronous parallel variants of the basic method. In addition, this approach has been demonstrated to be very effective in solving very large versions of the Air Force Patient Distribution System models. In fact, by using this algorithm we have been able to solve on the Sequent multiprocessor problems of this class that are much larger than those reported in the literature. This technique will also provide an excellent vehicle for future research involving hybrid parallelism, in which certain tasks (for example, the solution of linear subproblems) are handled in data parallel mode using massive parallelism, whereas others (coordination steps) are treated via control parallelism at the same time, using the unique ability of the CM-5 to support both parallel paradigms.

In my second major area of research, the focus is on problems in which data or variables may be regarded as corresponding to a domain comprised of square, cubical, or hypercubical cells. Each cell corresponds to a task, and the problem is to allocate the cells among the processors of a parallel computer in such a way as to balance the loads among the processors while minimizing total communication between processors. By reformulating this problem in geometric terms, we were able to develop a procedure that generates optimal solutions for many problem subclasses and provides good lower bounds in the general case. Research is continuing on extensions beyond the original database application to problems of domain decomposition and to different models of interprocessor communication.
2. CPO REPORTS & PAPERS


in Naval Research Logistics Quarterly.


3. TALKS BY CPO STAFF

R. De Leone


4. "Parallel Asynchronous Methods for Large Sparse Linear Programs and Linear Complementarity Problems" Universita' di Salerno, Salerno, Italy, June 1990.


M. C. Ferris


4. "Parallel constraint distribution for convex programs", ORSA/TIMS Joint National
Meeting, Philadelphia; October 1990.


O. L. Mangasarian


7. "Neural network training via linear programming with application to medical


R. R. Meyer


3. CPO Ph.D. STUDENTS
SUPPORTED BY AFOSR, NSF & UW GRANTS

1. Kristin Bennett (Mangasarian)
2. Menglin Cao (Ferris)
3. Chunhui Chen (Mangasarian)
4. Stephen Dirkse (Ferris)
5. Stephen Palzewicz (De Leone, until 12/90)
6. Jun Ren (Mangasarian)
7. Gary Schultz (Meyer, Ph.D. final oral on 9/91)
8. Mikhail V. Solodov (Mangasarian)
9. William Nick Street (Mangasarian)
10. Mary Tork Roth (De Leone)
11. Robert Welch (Ferris, until 5/91)
12. Jonathan Yackel (Meyer)
5. SYMPOSIUM ON PARALLEL OPTIMIZATION 2

With CPO support, a Symposium on Parallel Optimization in Madison was held during July 23-25, 1990. As was the case for the first Symposium on Parallel Optimization held in Madison August 10-12, 1987, refereed proceedings of this Symposium were published. For the Symposium on Parallel Optimization 2 the proceeding were published as Volume 1, Number 4 of the SIAM Journal on Optimization in November of 1991. This volume was edited by O.L. Mangasarian and R.R. Meyer. Its table of contents is reproduced below.
6. CPO VISITORS AND SPEAKERS


Michael C. Ferris & Olvi L. Mangasarian, University of Wisconsin, "Parallel distribution


7. Acquisition of CM-5 supercomputer

In September 1990, the CPO faculty members participated in an equipment proposal to the NSF Institutional Infrastructure program for the acquisition of new parallel computers for the Computer Sciences Department. This proposal was funded in 1991 at the level of $2,000,000 plus additional matching funds from the College of Letters and Science and the Graduate School. The first supercomputer acquired with this funding was a Thinking Machines Corporation CM-5 with 64 processors, installed in the Computer Sciences Department in September, 1991. Our department was one of only a handful of groups to obtain the CM-5 in its widely publicized initial distribution in September. This computer architecture is the first to attain one of the major computing goals of this century—scalability to teraflop computing rates. Each processor in the system will deliver up to 128 megaflops, and the architecture is designed to efficiently support configurations of thousands of processors. The CM-5 is also the first machine with the capability of supporting both major parallel computing paradigms—data parallelism, in which data is distributed among processors which subsequently execute the same instruction or set of instructions between synchronized communication steps, and control parallelism, in which processors may execute completely different programs and communicate asynchronously. As described in the research narratives of Section 1, for a broad variety of applications the four CPO faculty are developing and implementing methods that utilize both of these forms of parallelism. Thus, the CM-5 offers the unique opportunity to experiment with both parallel modes on the same supercomputer, as well as to efficiently implement hybrid parallel algorithms that have some subtasks that can utilize data parallelism and other subtasks for which control parallelism is more appropriate.
3. Period 3

October 1, 1991 - September 30, 1993
3 Activities

3.1 Research Areas of Investigators

O.L. Mangasarian
- Mathematical Programming in Neural Networks (with Kristin P. Bennett)
- Neural Networks in Medical Diagnosis and Prognosis (with Kristin P. Bennett, W. Nick Street and William H. Wolberg)
- Parallel Constraint and Variable Distribution (with Michael C. Ferris)
- Error Bounds in Mathematical Programming (with Michael C. Ferris and Jun Ren)
- Nonlinear Programming as Unconstrained Optimization (with Mikhail V. Solodov)
- General Convergence Theory for Unconstrained Parallel Optimization
- Generalized Complementarity Problems

R.R. Meyer
- Tiling for Optimal Parallel Domain Decomposition
- Barrier-based Decomposition for Large-Scale Optimization
- Resource-directed Multicommodity Optimization (with R. De Leone)
- Operator-splitting for Parallel Optimization (with R. De Leone)

M. C. Ferris
- Parallel Variable and Constraint Distribution (with O.L. Mangasarian and J. Horn)
- Operator Splitting Methods (with J. Eckstein)
- Callable Program Library (with S. Dirkse and T. Rutherford)
- Nonmonotone line search (with S. Lucidi)
- Gauss-Newton Methods for Complementarity Problems (with D. Ralph, J. Burke and L. Qi)
- Solution methods for Affine Variational Inequalites (with M. Cao and S. Billups)
- Weak Sharp Minima (with J. Burke and O.L. Mangasarian)

R. De Leone
- Massively Parallel Solution of Linear and Quadratic Network Flow Problems.
- Resource-directed Multicommodity Optimization (with R. Meyer).
- Serial (with R. Cerulli) and Parallel Auction Algorithms for Network Flow Problems (with P. Tiwari and B. Narendran).
- Optimization problems in radioterapy cancer treatment (with J. Deasy and T. Mackie).
3.2 Research Assistants

**O.L. Mangasarian**


**R.R. Meyer**


**M. C. Ferris**

- Jeffrey Horn, AFOSR and NSF Support: “Parallel solution of block structured problems”. Ph.D. expected August 1996.

**R. De Leone**

- Tia Newhall, AFOSR Support: “Massively parallel solution of structured mathematical programs”
3.3 Papers and Technical Reports

O.L. Mangasarian


R.R. Meyer


R. De Leone


3.4 Talks

O.L. Mangasarian


9. Neural networks via mathematical programming, University of California at San Diego, La Jolla, CA March 1993.


R.R. Meyer

1. Large Scale Multicommodity Transportation Problems, Joint Operations Research/Artificial Intelligence Workshop on Transportation Planning, Pittsburgh October 1991


8. Parallel Barrier-Based Algorithms for Multicommodity Flows, Polytechnic University of Madrid, Madrid, Spain September 1992


M. C. Ferris


R. De Leone


5. *Approcci Poliedrali per la Soluzione di Problemi di Programmazione Intera*, University of Roma, Rome, Italy January 1992

6. *Optimal Resource Allocation and Binding of Non-Pipelined Design*, University of Salerno, Salerno Italy January 1992


8. *Parallel Solution of Extremely Large Quadratic Programs*, University of Camerino, Camerino, Italy June 1992

3.5 Outside Visitors and Speakers


- **Prof. Evgeny Golshtein**, USSR Academy of Sciences, October 10, 1991, Parallel Constraint and Variable Distribution in Optimization

- **Prof. Leslie Valiant**, Harvard University, October 15-17, 1991, Learning with Discrete Neural Models


- **Dr. Raffaele Cerulli**, University of Salerno, Italy, January 1992-May 1992

- **Dr. David Johnson**, AT&T Bell Labs, April 15-16, 1992, The Traveling Salesman Problem

- **Prof. Richard W. Cottle**, Stanford University, May 14-16, 1992, Some Open Questions on Matrix Classes in the Linear Complementarity Problem

- **Prof. Luigi Grippo**, University of Rome, Italy, May 13-16, 1992, Differentiable Exact Penalty Functions: An Overview

- **Dr. Domenico Conforti**, University of Calabria, Italy, May 13-16, 1992

- **Dr. Ilya Dikin**, Siberian Energy Institute, Russia, May 19, 1992, The convergence of sequence of dual variables

- **Dr. Danny Ralph**, Cornell University, July 15-22, 1992, Decomposition of Discrete-Time Optimal Control Problems

- **Prof. George F. Corliss**, Marquette University and Argonne National Laboratories, October 20, 1992, The Functionality of ADIFOR

- **Prof. Klaus Ritter**, Technical University of Munich, September-October, 1992, A Super-linearly Convergent Algorithm for Singular-Point Minimization

- **Prof. Rong-Jaye Chen**, Department of Computer Science and Information Engineering, National Chiao Tung University, Taiwan, September 1992-August 1993, A Systolic Design for Dynamic Programming

- **Prof. B. T. Polyak**, Institute for Control Science, Moscow, Russia November 19, 1992, Multilinear programming

- **Prof. Norman Curet**, UW-Stevens Point December 3, 1992, On the Incremental Primal-Dual Algorithm for Network Optimization

- **Prof. Thomas F. Rutherford**, University of Colorado, December 10-11, 1992, Sequential Joint Maximization

- **Dr. Domenico Conforti**, University of Calabria, Italy, January 1993-December 1993


- Dr. Roberto Musmanno, University of Calabria, Italy, April 7-9, 1993


- Symposium on Parallel Optimization 3: Twenty-one invited presentations were given at this international symposium organized by CPO and held in Madison 7-9 July, 1993. Details are given in the next section of this report.
3.6 Symposium on Parallel Optimization 3

Twenty-one invited presentations were given at this international symposium organized by the Center for Parallel Optimization and held in Madison 7-9 July, 1993. Refereed proceedings will be published as a special issue of the SIAM Journal on Optimization in 1994. An alphabetical list of speakers is given below.

• Dr. Kristin P. Bennett  
  Dept. of Operations and Info. Mgmt.  
  University of Connecticut  
  368 Fairfield, U-41  
  Storrs, CT 06269

Professor Olvi L. Mangasarian  
Computer Science Department  
1210 W. Dayton Street  
University of Wisconsin  
Madison, WI 53706

"Parallel Multicategory Discrimination"

• Professors Robert R. Meyer and Renato De Leone  
  Computer Science Department  
  1210 W. Dayton Street  
  University of Wisconsin  
  Madison, WI 53706

"Coordinating Mechanisms in Coarse-Grained Decomposition"

• Professor John E. Dennis  
  Center for Research on Parallel Computing  
  Fondren Library/CITI  
  Rice University  
  Houston, Texas 77005

"Multidisciplinary Optimization"

• Dr. Jonathan Eckstein  
  Thinking Machines Corporation  
  245 First Street  
  Cambridge, MA 02142

"Parallel Branch-and-Bound Algorithms for General Mixed Integer Programming on the CM-5"

• Professors Michael C. Ferris and Olvi L. Mangasarian  
  Computer Sciences Department  
  1210 W. Dayton Street  
  University of Wisconsin  
  Madison, WI 53706

"Parallel Variable Distribution"
• Professor Alexei A. Gaivoronski  
ITALTEL  
Central Research Laboratories  
I-20019 Castelletto di Settimo  
Milanese (MI), Italy  

"Convergence of Parallel Backpropagations Algorithm for Neural Networks"

• Professor Luigi Grippo  
Univ. degli Studi di Roma "La Sapienza"  
Dipartimento di Infor. e Sistemistica  
Via Buonarroti 12  
00185 Roma, Italy  

"A Class of Unconstrained Minimization Methods for Neural Network Training"

• Professor T. C. Hu  
Computer Science Department  
University of California at San Diego  
La Jolla, CA 92093  

"Parallel Dynamic Adaptive Searching Algorithms"

• Dr. Tom Luo  
Communications Research Laboratory  
Faculty of Engineering  
McMaster University  
1280 Main Street West  
Hamilton, Ontario L8S 4K1, Canada  

Professor Paul Tseng  
Department of Mathematics, GN-50  
University of Washington  
Seattle, Washington 98195  

"Convergence Analysis of Backpropagation Algorithm for Neural Networks with Arbitrary Error Functions"

• Mr. Rich Maclin and Professor Jude Shavlik  
Computer Science Department  
1210 W. Dayton Street  
University of Wisconsin  
Madison, WI 53706  

"Optimizing Objective Functions that Have Many Local Minima: Combining Multiple Neural Networks Trained in Parallel"
• Professor Olvi L. Mangasarian  
  Computer Science Department  
  1210 W. Dayton Street  
  University of Wisconsin  
  Madison, WI 53706  

"Serial and Parallel Backpropagation Convergence via Nonmonotone Perturbed Minimization"

• Professors Sanjay Mehrotra and Robert Fourer  
  Department of Industrial Engineering  
  and Management Sciences  
  Northwestern University  
  Evanston, IL 60208  

"Solving Large Sparse Linear Programs Using the CM-2"

• Dr. Jorge J. Moré  
  Mathematics and Computer Science Div.  
  Argonne National Laboratory  
  9700 South Cass Avenue  
  Argonne, IL 60439  

"On the Evaluation of Large-Scale Problems on Serial and Parallel Machines"

• Professor John M. Mulvey  
  Department of Civil Engineering  
  Princeton University  
  Princeton, New Jersey 08544  

"Testing a Distributed Scenario Decomposition Method for Large Stochastic Programs"

• Professor Jong-Shi Pang  
  Department of Mathematical Sciences  
  The Johns Hopkins University  
  Baltimore, Maryland 21218  

"Serial and Parallel Computation of Karush-Kuhn-Tucker Points via Nonsmooth Equations"

• Professor Dr. Klaus Ritter  
  Institut für Mathematik und Statistik  
  Technische Universität Munchen  
  Arcisstrasse 21  
  8000 Munchen 2, Germany  

"A Stochastic Method for Constrained Global Optimization"
• Professor J. Ben Rosen
  Computer Science Department
  4-192 EE/CSci Building
  University of Minnesota
  200 Union Street S.E.
  Minneapolis, Minnesota 55455

  "Large-Scale Nonlinearly Constrained Optimization on a 1024-Processor nCUBE"

• Drs. Alan Whisman and Erick Wikum
  U.S. Air Force
  HQ MAC/XPY
  Scott AFB, IL 62225

  "Robust Estimates for the Airlift Mobility Command Channel System"

• Dr. Margaret H. Wright
  ATT Bell Laboratories
  Room 2C-462
  600 Mountain Avenue
  Murray Hill, NJ 07974

  "Exploiting Parallelism in Solving Large-Scale Least-Squares Problems from System Identification Programming"

• Dr. Xiru Zhang
  Thinking Machines Corporation
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  "Massively Parallel Computing in Protein Structure Prediction and Time Series Analysis"

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  "Scalable Massively Parallel Algorithms for Robust Optimization"