1996-97 Activity Report

Center for Applied Optimization

Modeling and Computation for Engineering, Science and Industry

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The **Center for Applied Optimization** at the University of Florida is an interdisciplinary center which encourages joint research and applied projects among faculty from engineering, mathematics and business. It also encourages increased awareness of the rapidly growing field of optimization through publications, conferences, joint research and student exchange. It was founded in September 1992. The co-directors are Drs. Donald Hearn and Panos Pardalos of the Department of Industrial and Systems Engineering and Dr.William Hager of the Department of Mathematics. Center affiliates include faculty from Industrial and Systems Engineering, Civil Engineering, Aerospace Engineering, Mechanics and Engineering Science, Electrical Engineering, Computer and Information Sciences, Chemical Engineering, Mathematics, and Decision and Information Sciences.

Optimization may be characterized as determining the maximum benefit of a decision process by the use of mathematical modeling. For example, the most well-known technique, linear programming, has long been used by large companies in resource allocation, capital budgeting, production planning, facility location, vehicle routing and scheduling and many other decision problems. Typically these problems are very large with many variables and restrictions on the decision process. With optimization modeling and the help of fast computers for numerical computation, organizations of all sizes can now make more accurate and beneficial decisions.

Optimization also embodies fundamental mathematical principles which arise in technical areas such as engineering design, control of dynamic processes, and systems analysis. Numerical optimization plays a key role in solving models of many such complex processes. Thus an important activity of the Center is the development of optimization software.

Affiliated Faculty and 1996-97 Visitors

Industrial and Systems Engineering:

Sherman Bai, Ph.D. (MIT), Operations Research, Manufacturing Systems

Richard Francis, Ph.D. (Northwestern), Location Theory, Facilities Design

Donald Hearn, Ph.D. (Johns Hopkins), Operations Research, Optimization, Transportation Science

Tom Kisko, MS (Florida), Robotics, Digital Simulation

Panos Pardalos, Ph.D. (Minnesota), Combinatorial and Global Optimization, Parallel Computing

Suleyman Tufekci, Ph.D. (Georgia Tech), Network Modeling, Virtual Manufacturing, Integrated Product and Process Design, Logistics

Mathematics:

Gang Bao, Ph.D. (Rice), Inverse and Optimal design Problems for Partial Differential Equations

William Hager, Ph.D. (MIT), Numerical Analysis, Optimal Control

Bernhard Mair, Ph.D. (McGill), Inverse Analysis

Andrew Vince, Ph.D. (Michigan), Combinatorics, Graph Theory, Polytopes, Combinatorial Algorithms, Discrete Geometry

David Wilson, Ph.D. (Rutgers), Image Processing

Civil Engineering:

Kirk Hatfield, Ph.D. (Massachusetts), Water Quality Modeling, Optimization in Environmental Modeling

Aerospace Engineering, Mechanics & Engineering Science:

Raphael Haftka, Ph.D. (UC San Diego), Structural and Multidisciplinary Optimization, Genetic Algorithms

Electrical Engineering:

William Edmonson, Ph.D. (N.C. State), Adaptive Filtering, Parametric Estimation, Genetic Algorithms, Intelligent Systems, Optimization

Decision & Information Sciences:

Harold Benson, Ph.D. (Northwestern), Multi-criteria Optimization, Global Optimization

Selcuk Erenguc, Ph.D. (Indiana), Optimal Production Planning

Computer & Information Science & Engineering:

Gerhard X. Ritter, Ph.D. (Wisconsin), Computer Vision, Image Processing, Pattern Recognition, Applied Mathematics

Chemical Engineering:

Oscar D. Crisalle, Ph.D. (UC Santa Barbara), Process Control Engineering, Modeling and Optimization

1996-97 Visitors:

Motakuri Ramana, Ph.D. (Johns Hopkins), Semidefinite Programming, Network Optimization, Multiquadratic Optimization, Graph Theory, Complexity Theory

Xin Liu, Ph.D. (Chinese Academy of Sciences), Protein Folding, Global Optimization

Yasutoshi Yajima, Ph.D. (Tokyo Institute of Technology), Global Optimization, Combinatorial Optimization

Tania Querido, Ph.D. (Universide Federal do Rio de Janeiro) Combinatorial Optimization, Graph Theory, Algorithms

Reiner Horst, Global Optimization, Mathematical Programming

Current Ph.D. Students in Optimization

Mehmet Akansel is working on lot streaming problems. His proposal exam was Fall 1996. Expected graduation will be fall of 1997. Advisor: *Tufekci.*

Latif Albusairi is working on network flow modeling of emergency evacuations. Expected graduation will be the fall of 1997. Advisor: *Tufekci.*

Mohammed Altuwaim is working on the optimization of periodic processes that can be described accurately using bilinear representations. Advisor: *Crisalle.*

V.R. Basker is working on optimization problems concerning the minimization of robustness measures, such as the structured singular value, and the Nyquist robust-stability margin. Advisor: *Crisalle.*

George Boger continues his work on heuristics and exact procedures for globally solving multiplicative programming problems. During the past year he co-authored a publication with his advisor on a new heuristic for the linear multiplicative programming problem. George will take the oral portion of his Ph.D. qualifying exam in August, 1997. Advisor: *Benson.*

Joongkyu Choi is working on optimal production control. Advisor: *Bai.*

Juan Cruz is working at NASA Langley Research Center on use of optimization for finding weak points in models of physical response.

Jon D. Engelstad is working on the optimization of emulsion polymerization reactors, with an emphasis on modeling and control. Advisor: *Crisalle.*

Kostas Hrissagis is working on mixed-objective optimization problems, including l_1/H_∞, and l_2/H_∞ control design for stability robustness and performance. Advisor: *Crisalle.*

Dukwon Kim is developing an algorithm for solving the general capacitated nonconvex cost network flow problems using a dynamic slope scaling procedure. Advisor: *Pardalos.*

Wen Lee is working on solving the harmonic retrieval problem using interval methods of optimization. Advisor: *Edmonson.*

Yihui Li Optimization of manufacturing systems. Advisor: *Bai.*

Boyang Liu is working on optimization of wing structures made from composite materials by genetic algorithms.

H. Michael Mahon is working on optimal l_1 control theory, with applications to robust controller synthesis. Advisor: *Crisalle.*

Soon Chul Park is working on the use of optimization theory in developing pivoting strategies to minimize fillin during the Cholesky factorization of a sparse matrix. Advisor: *Hager.*

Eduardo Pasiliao is working on Survivable Networks. Advisor: *Pardalos.*

Leonidas Pitsoulis completed his Masters degree in 1994. He is writing a thesis on *A GRASP for the Quadratic Assignment Problem* and is working on parallel algorithms for nonlinear assignment problems for his Ph.D. dissertation. Advisor: *Pardalos.*

Raluca Rosca is working on comparison of optimization against risk based on probabilistic models and on fuzzy set models. Advisor: *Haftka.*

Erjiang Sun will take the written portion of his Ph.D. qualifying exam in August, 1997. He anticipates doing research in the area of Multiple Criteria Optimization. Advisor: *Benson.*

Satchi Venkatraman is working on use of response surfaces for design optimization of structures of launch vehicles. Advisor: *Haftka.*

Gerhard Venter is working on use of response surfaces for engineering optimization. Advisor: *Haftka.*

Roberto Vitali is working on use of response surfaces for combining simple and complex models. Advisor: *Haftka.*

Shuang Yang is designing computer-based algorithms that track the epicardial and endocardial borders of the left ventricle of the heart. These methods are to be based on optimization methods that have evolved from the calculus of variations—in particular, a technique known as optical flow. Advisor: *Wilson.*

Kuo-Huei Yen is developing optimal algorithms for the computation of robust stability margins of dynamical systems affected by parametric uncertainties of the affine and linear types. Advisor: *Crisalle.*

Mehmet B. Yildirim is working on network optimization. Advisor: *Hearn.*

Center for Applied Optimization Ph. D. Graduates

Hsin-Der Chen graduated in August, 1993. His dissertation research on *New Techniques for Lotsizing Models* has led to four publications, and he developed a new pivoting strategy for linear programming which is the subject of an additional publication. During 1993-94 he was a research associate of the Center. In Fall, 1994 he accepted an assistant professorship with Providence University, Taichung, Taiwan. Advisors: *Hearn and Lee.*

Mohsen El Hafsi defended his Ph.D. thesis on *The Optimal Dynamic Setup Problem for Manufacturing Systems* in July, 1995. During 1995-96 he was a postdoctoral fellow in the ISE Department. He has a tenure-track position at the Gary Anderson Graduate School of Management of the University of California at Riverside. Advisors: *Bai and Sivazlian.*

Luana Gibbons graduated in August, 1994, writing a dissertation on continuous and discrete approaches to the maximum clique problem. She is currently working for Cutting Edge Optimization, Inc., Atlanta, GA. Advisors: *Hearn and Pardalos.*

Jeffery Herrmann graduated in August, 1993, writing a dissertation entitled *An Investigation of Production Scheduling Problems Motivated by Semiconductor Manufacturing.* After two years as a visitor, he has taken a position as assistant professor in the Mechanical Engineering Department and the Institute for Systems Research at the University of Maryland, College Park. Advisor: *Lee.*

Alex Hipolito completed his Ph.D. in August, 1993, writing a dissertation on *A Weighted Least Squares Approach to Direction Finding in Mathematical Programming.* A paper from his research was a finalist in the 1993 Operations Research Society competition. After two years in a postdoctoral position at Delft University of Technology in the Netherlands, he is now an assistant professor in the Department of Mathematics, University of the Philippines. Advisor: *Hearn.*

Tom Horak defended his dissertation entitled *Optimal Component Placement* in May, 1994, and has a visiting position at Rutgers University, Newark. Advisor: *Francis*

Franz-Josef Kraëmer defended his dissertation on essays in production scheduling and graduated in Summer, 1994. Advisor: *Lee.*

George Vairaktarakis wrote a dissertation on multicriteria decision making in production management and graduated in Summer, 1994. He is currently an assistant professor in the Business School, Marquette University. Advisor: *Lee.*

Bassam Khoury completed his Ph.D. dissertation on *The Steiner Problem in Graphs,* and his research resulted in three journal publications. He graduated in December, 1993. Advisor: *Pardalos.*

Hari Pulapaka received his Ph.D. in 1995 in the field of graph theory and polytopes. His dissertation was entitled *Non-revisiting Paths and Cycles in Polyhedral Maps.* He is employed at Valdosta State University. Advisor: *Vince.*

Brenda Rayco MS (Illinois) defended her Ph.D. dissertation on *Algorithmic Approaches to Demand Point Aggregation for Location Models,* and graduated May, 1996. Her dissertation will be submitted to the 1996-97 INFORMS SOLA (Section on Locational Analysis) Ph.D. dissertation competition. She is currently at the FAMU-FSU Department of Industrial Engineering. Advisor: *Francis.*

Purandar Sarmah received the Ph.D. in 1993, writing a dissertation on *Application of Eigenvalue and Eigenvector Sensitivity in Eigencomputations.* He currently has a position with Bellcore, Piscataway, NJ. Advisor: *Hager.*

Chun-Liang Shih completed his Ph.D. dissertation entitled *Active Set Strategies in Optimization* and graduated May, 1995. He was hired by the Department of Applied Mathematics, Kaohsiung Polytechnic Institute, Taiwan. Advisor: *Hager.*

Elliott Williams defended his dissertation examination on *Solution Techniques for Problems in Lot Streaming* and graduated in Spring, 1995. He has a position with Ryder Corp., Miami, FL. Advisor: *Tufekci*.

Yongzhi Yang received his Ph.D. in 1994 in the field of graph theory. His dissertation was entitled *Edge Reconstruction in Graphs*. He is employed at Alabama State University. Advisor: *Vince*.

Current Research Projects in Optimization

- **Decision Modeling for St. Johns River Water Management District (SJRWMD) Water Supply Strategies.** This model involves a mixed integer program for determining optimal future sources of water supply while minimizing environmental effects. PIs: *Hatfield and Hearn.* Source of funds: *St. Johns River Water Management District.*

- **Traffic Assignment Models for Congestion Toll Pricing.** Recent advances in intelligent highway system technology makes practical an old idea: charge tolls for the use of congested links. This project concerns a study of the set of all toll vectors which will cause the user-optimal problem to be system optimal. PI: *Hearn.* Source of funds: *National Science Foundation.*

- **Fast Algorithms for Lotsizing Models.** The fundamental single and multi-item lotsizing problems of production planning have been investigated in the Ph.D. research of Hsin-Der Chen. A new approach based on continuous dynamic programming concepts has led to algorithms which are orders of magnitude faster than prior methods. User-friendly software of the algorithms has been developed for PCs. PIs: *Hearn and Lee.* Source of funds: *National Science Foundation and University of Florida EIES.*

- **Accelerated Decomposition Methods and Large-Scale Optimization Applications.** The overall objective of this research is to increase the efficiency and applicability of large-scale optimization methods. Applications include models in operations research, production systems, electrical and civil engineering and the sciences. PI: *Hearn.* Source of funds: *National Science Foundation.*

- **Traffic Assignment Algorithms.** Accelerated algorithms for traffic assignment and other congested network models are under development. The algorithms are applied to models of urban traffic, natural gas pipelines, urban water systems and in percolation systems. PI: *Hearn.* Source of funds: *National Science Foundation and University of Florida EIES.*

- **New Algorithms for Maximum Clique Problems.** New continuous and discrete algorithms have been developed for this fundamental graph problem in the dissertation work of Luana Gibbons. The problem has application in information retrieval, pattern recognition, coding theory, signal transmission and experimental design. The new methods offer speedups which are orders of magnitude faster than prior methods on many classes of graph problems. We are also investigating local optimality and related properties for the Motzkin-Strauss formulation of the problem. PIs: *Hearn and Pardalos.* Source of funds: *National Science Foundation and University of Florida EIES.*

- **Analysis and Algorithms for Semidefinite Programming.** The Semidefinite Programming Problem is a generalization of LP, and it has been demonstrated to have applications to several combinatorial optimization problems. Currently, investigations are being carried out concerning aspects such as duality theories, algorithmic techniques and applications to perfect graph theory. PI: *Ramana.*

- **Quadratic Assignment Algorithms.** New very efficient parallel and sequential computational algorithms have been developed for finding suboptimal (and global) solutions of the quadratic assignment problem (this is a joint research effort with M.G.C. Resende and K.G. Ramkrishnan from Bell Labs). Quadratic assignment problems have many applications in location theory, distributed computing, combinatorial data analysis and VLSI design. Recently, a book was published (with H. Wolkowicz) on "Quadratic Assignment and Related Problems," in the DIMACS Series, American Mathematical Society. Currently, Leonidas Pitsoulis is working on general algorithms (sequential and parallel) for nonlinear assignment problems. PI: *Pardalos.*

- **Parallel Algorithms for Integer Programming.** An efficient algorithm for quadratic 0-1 programming based on branch and bound strategies and dynamic preprocessing techniques was developed (with G. Rodgers, IBM). The algorithm has been parallelized for shared memory and distributed memory computers, using new load balancing techniques. Ongoing research focuses on improving the performance of the algorithm using efficient data structures and heuristics. An algorithm was also

developed (with S. Jha, Carnegie Mellon University) based on graph separator techniques that can be used to solve the general pseudoboolean problems. In addition, several parallel heuristics have been studied (including parallel tabu search and GRASP). A conference was organized (jointly with M.G.C. Resende and K.G. Ramakrishnan) on "Parallel Processing of Discrete Optimization Problems." It was held at DIMACS (Center for Discrete Mathematics and Theoretical Computer Sciences), April 28-29, 1994. The proceedings of this conference appeared in the DIMACS Series published by the American Mathematical Society. PI: *Pardalos.* Source of Funds: *DIMACS through NSF grants* and from the European Community Program *Human Capital and Mobility.*

- **Global Minimization of Nonconvex Energy Functions.** Several algorithms have been developed for the global optimization of nonconvex energy functions. A conference was organized (jointly with D. Shalloway and G. Xue) "Global Minimization of Nonconvex Energy Functions: Molecular Conformation and Protein Folding." It was held at DIMACS (Center for Discrete Mathematics and Theoretical Computer Sciences) March 20-21, 1995. The proceedings of this conference appeared in the DIMACS Series published by the American Mathematical Society. PI: *Pardalos.* Source of Funds: *National Science Foundation.*

- **Nonconvex Network Flow Problems.** Several algorithms have been developed for solving minimum concave cost network flow problems (with G. Guisewite). It has been shown that such problems can be solved in polynomial time if the number of concave costs is fixed and the other costs are linear. The overall objective of this research is to apply these results to an efficient algorithm for solving nonconvex network flow problems. PI: *Pardalos.*

- **Aggregation for Large Scale Location Problems.** This grant has a subcontract with the University of Iowa. Faculty involved there are Dr. Timothy J. Lowe, College of Business Administration, and Dr. Gerard Rushton, Department of Geography. Also a consultant on the grant is Dr. Arie Tamir, Department of Statistics, School of Mathematical Sciences, Tel-Aviv University Ramat-Aviv, Tel-Aviv, Israel. PI: *Francis.* Source of funds: *National Science Foundation.*

- **Lipschitz Stability and its Application to Numerical Analysis in Optimal Control.** Stability analysis is used to analyze numerical algorithms for optimal control problems. PI: *Hager.* Source of funds: *National Science Foundation.*

- **Analysis and Optimization of Elastic Materials.** This project is to examine problems related to minimal reflection and the optimal design of layered elastic materials. PI: *Hager* Source of funds: *Army Research Office.*

- **Discrete Approximations in Variation Problems** PI: *Hager.* Source of funds: *National Science Foundation.*

- **Simulation Optimization of Dynamic Processes Using Frequency and Wavelet Analysis.** PI: *Bai.* Source of funds: *National Science Foundation-ERC.*

- **Inverse Problems in Diffractive Optics and Wave Propagation**. PI: *Bao.* Source of Funds: *National Science Foundation Applied Math. Program.*

- **Modeling and Optimization of Diffractive Optical Structures**. PI: *Bao.* Source of Funds: *National Science Foundation University-Industry Program in Math. Sci.*

- **Global Approaches in Multiple Objective Optimization.** This is an open-ended project for finding and creating global optimization techniques for representing the efficient sets in multiple objective linear and nonlinear programming problems. To date, a"shooting" approach has been developed and tested on linear problems. Other approaches are currently being investigated. PI: *Benson.*

- **Citrus Rootstock Selection via Multiple Objective Optimization.** This project involved developing and applying a multiple objective linear programming model to the problem of selecting appropriate mixes of citrus rootstocks to use in Florida's citrus groves. The solution method is an enhanced version of an interactive algorithm for multiple objective linear programs called STEM. We

found that STEM performs poorly in practice with citrus growers unless it is enhanced by finding the minima of the criteria over the efficient set as benchmarks for the decision maker. We developed a fast, accurate heuristic for this purpose to help obtain citrus rootstock plans for groves in the Fort Pierce area of Florida. PI: *Benson.*

- **A Heuristic for Multiplicative Programming.** This project involved developing a fast but accurate approximate procedure for solving the global optimization problem of minimizing a product of linear functions over a polyhedron. A promising heuristic that uses multiple objective programming ideas has been developed and tested computationally. PI: *Benson.*

- **A Survey of Concave Minimization Algorithms.** Many approaches and algorithms for solving the important global optimization problem of minimizing a concave function over a convex set have now been proposed. The survey provided a framework for describing and categorizing these numerous methods and evaluated the advantages and disadvantages of each method. PI: *Benson.*

- **Fast Approaches for Solving the Modular Design Problem.** The modular design problem is an optimization model for minimizing the total cost of producing modules made of constituent parts of various types. This problem has major benefits when used at the design stages of a production process to minimize product costs. Mathematically, it can be modeled in a variety of ways. This project seeks to develop a fast algorithm for finding optimal solutions to large-scale versions of this problem. Part of the approach will involve investigating alternate ways of representing the problem. The remainder will involve tailoring nonlinear or global optimization approaches to the chosen formulation to create the algorithm desired. PIs: *Benson and Pardalos.*

- **Minimizing Convex and Concave Functions over Efficient Sets.** The problem of optimizing a function over the efficient set of a multiple objective linear programming problem has become the subject of many recent studies due to its practical importance in analyzing and solving multiple objective linear programs. This project seeks to analyze this problem for cases when the objective function is convex or concave and, by using recent developments from the field of global optimization, to develop algorithms for solving the resulting problems. PI: *Benson.*

- **Quasi-Concave and Concave Minimization: Some New Results.** Some important theoretical properties of quasi-concave and concave minimization have either been overlooked or falsely stated to date in the literature. This project will present some important new mathematical properties of quasi-concave and concave functions and minimization problems. PI: *Benson.*

- **Outcome Set Approaches in Optimization.** This project seeks to develop the theory and tools needed for solving large classes of mathematical programming problems more efficiently by working in the outcome space instead of taking the more traditional but cumbersome approach of working in the larger, more complex decision space. Initial stages will concentrate on the all-linear case. PI: *Benson.*

- **An Efficient Outcome Set Algorithm for Multiplicative Programming**. Using some of the ideas from outcome set theory, an efficient algorithm for solving the linear multiplicative problem will be developed. Central to the algorithm will be the use of Tuy cuts in the outcome space, rather than in the decision space. PI: *Benson.*

- **Algorithms for Lot-Streaming Problems.** In this project sublot sizes are established for minimizing the makespan. Several methods are developed for consistent and nonconsistent sublot sizes. PI: *Tufekci.* Source of funds: *University of Florida EIES.*

- **Dynamic Network Flows With Side Constraints.** Modeling emergency evacuations requires large dynamic networks with many additional constraints representing congestion effects. Solution algorithms are developed for solving these massive optimization problems. PI: *Tufekci.* Source of funds: *University of Florida EIES.*

- **Communication Network Design.** The availability of fiber optics and increasing demand for two-way audiovisual communication and interactive television has necessitated the study of feasible fiber optic communication network design for homes. This study develops optimization models for

determining optimal network configurations. PI: *Tufekci.* Source of funds: *University of Florida EIES.*

- **Project Networks and Time-Cost Tradeoff Problems.** In this work several algorithms are being developed for solving time-cost tradeoff problems. Heuristic procedures are under development. PI: *Tufekci.* Source of funds: *University of Florida EIES.*

- **Inverse Problems in Diffractive Optics and Wave Propagation.** We examine the mathematical issues and computational methods for solving the following three classes of problems: inverse and optimal design problems in diffractive optics, direct problems in nonlinear diffractive optics, and inverse problems in several dimensional wave propagation. PI: *Bao.* Source of funds: *National Science Foundation.*

- **Surface Enhanced Nonlinear Optical Effects.** The main topics of the project are: stability for inverse diffraction problems, direct modeling of scattering and diffraction of complicated nonlinear optical materials, and surface enhanced nonlinear optical effects. PI: *Bao.* Source of funds: *Research Development Awards (RDA), UF.*

- **The Greedy Algorithm and Coxeter Matroids**. Matroids are the natural setting for the greedy algorithm because the greedy algorithm solves the combinatorial optimization problem of finding the independent set with greatest total weight. A Coxeter matroid is a generalization of matroid, ordinary matroid being the case corresponding to the family of Coxeter groups usually denoted A_n, isomorphic to the symmetric group S_{n+1}. There is, associated with Coxeter matroids, a combinatorial opitimization problem that is also solved by the greedy algorithm. PI: *Vince.*

- **Industrial Process Optimization and Control**. PI: *Bai.* Source of funds: *National Science Foundation.*

- **Variable Complexity Optimization of Composite Structures.** Development of optimization strategies that combine accurate and expensive models with inexpensive and less accurate models for the design of composite panels. PI: *Haftka.* Source of funds: NASA.

- **Wing Structural Design by Genetic Algorithms and Homotopy Methods**. Development of two-level structural optimization methods for wing structural design, with genetic algorithms used at the lower level to design individual wing panels. PI: *Haftka.* Source of funds: Air Force Office of Scientific Research.

- **Variable Complexity Structural Optimization of Launch Vehicles**. Development of optimization strategies that combine accurate and expensive models with inexpensive and less accurate models for the design of launch vehicle structures. PI: *Haftka.* Source of funds: NASA.

- **Efficient Approximation for Structural Optimization under Multiple Damage Cases**. Development of approximations of structural response that allow inexpensive estimates of the effect of damage and changes in the structure. PIs: *Haftka and Garcelon.* Source of funds: NASA.

- **Position Emission Tomography: Analysis and Algorithms**. PIs: *Mair and Rao.* Source of Funds: *National Science Foundation.*

- **Tomography and Biomedical Imaging.** PI: *Mair.* Source of Funds: *DSR.*

- **Conference on Optimal Control**. PI: *Hager, Mair, and Bao.* Source of Funds: *National Science Foundation.*

Optimization Software Developed

- **RSDNET and RSDTA** are computer codes for solving congested network optimization models. They have been applied to problems in design of natural gas pipeline systems, percolation modeling used in the design of lightweight electromagnetic shielding, and to traffic network equilibrium problems (D.W. Hearn, S. Lawphongpanich and J. Ventura).

- **RSDTA II** enhances the RSDTA's features by additional toll estimation procedures for traffic network equilibria (Mehmet B. Yildirim, D.W. Hearn and M. Ramana).

- **LOTSIZE** is a Windows application for production planning which solves both single and multi-item capacitated lot size problems. The solution algorithms are from the Ph.D. dissertation of Hsin-Der Chen, and the Windows software was developed by KTH visiting student Ron Birk.

- **CBH** is a heuristic for the maximum clique problem based on a new nonlinear optimization formulation, and **VHP** is an exact algorithm. They have been extensively tested on DIMACS test problems and both are from the dissertation research of Luana Gibbons. Other exact algorithms are **C-P.f** developed by R. Carraghan and P.M. Pardalos and **P-R.f** based on a quadratic 0-1 formulation (P.M. Pardalos and G.P. Rodgers).

- **COVER and WTDCOVER** solve the basic geometrical problem of covering a point set (possibly weighted) with a circle of minimum radius by the Elzinga-Hearn algorithm. Applications include minimax facility location and computer graphics (D.W. Hearn and J. Vijay).

- **QUADNET** is an implementation of Hager's dual active set algorithm for the separable quadratic cost network flow problem. The code is available in both Fortran and Matlab (W.W. Hager and D.W. Hearn).

- **Q01SUBS** solves unconstrained quadratic 0-1 problems both for dense and sparse matrices, including concave quadratic minimization problems with box constraints (P.M. Pardalos and G. Rodgers).

- **QAPP** is an exact algorithm for solving quadratic assignment problems (P.M. Pardalos and J. Crouse), and there are two versions of **GQAP**, a greedy randomized adaptive search procedure (GRASP) for approximately solving dense and sparse problems.

- **REMS: Regional Evacuation Modeling System** is a network based traffic analysis system for emergency area evacuations (S. Tufekci).

- **ASCBM: Affine Scaling Central Bundle Method** solves unconstrained and bound constrained convex minimization problems. Designed for master problems that arise in decomposition and relaxation methods, it combines concepts from interior point algorithms, weighted least squares analysis, smooth optimization and bundle techniques for nonsmooth optimization (A. Hipolito and D. W. Hearn).

Optimization Journals, Newsletter and Book Series

- *The Journal of Global Optimization*, published by Kluwer Academic Press, is the world's leading journal in global and nonconvex optimization. Panos M. Pardalos is Editor-in-Chief, and Harold Benson is an Associate Editor. The journal publishes papers dealing with every theoretical, computational and applicational aspect of global optimization. Optimization is understood in the widest sense including, for example, nonlinear, stochastic and combinatorial programming, control, games, approximation algorithms, and systems of nonlinear equations. Besides research articles and expository papers on theory and algorithms of global optimization, papers on numerical experiments, applications, software development, open research problems, and related book reviews are also published. Eight issues are published annually.

- *Computational Optimization and Applications*, which emerged in 1992 in response to the growth in computing technologies relevant to the field of optimization, is increasing its publication frequency from six issues per year to nine. William W. Hager is Editor-in-Chief, and Panos Pardalos and Donald Hearn are Associate Editors. Papers dealing with all aspects of computational optimization — algorithm development and comparisons, implementation issues, modeling systems, and applications — are published. Research with a cross-disciplinary flavor is particularly encouraged; Researchers from industry are encouraged to collaborate with those from academia, while others with expertise on theoretical aspects of algorithm development are encouraged to collaborate with computational scientists. The journal maintains a library of computer software associated with papers published in the journal.

- *Optima* is the newsletter of the Mathematical Programming Society. It contains society news, articles on optimization, information on conferences, and book reviews. D. W. Hearn has been Editor since 1980. It is now on the web at www.ise.ufl.edu/∼optima.

- *Applied Optimization* is a new book series being published by Kluwer with Panos Pardalos and Donald Hearn as Editors. The goal of the series is to publish state of the art expository research covering all topics in applied optimization. In addition the series will include texts and monographs which are suitable for graduate level courses in engineering, business, applied mathematics, operations research and computer science.

- *Nonconvex Optimization and Application* is a series of books published by Kluwer and edited by Panos Pardalos and R. Horst.

- *Combinatorial Optimization* is a series of books published by Kluwer and edited by Panos Pardalos and D. Du.

Center for Applied Optimization Conference Books

- Hager, W.W., D.W. Hearn and P.M. Pardalos, "Large Scale Optimization: State of the Art," *Kluwer Academic Publishers*, 1996, ISBN 0-7923-2798-5.

  This book is a collection of papers presented at the Large Scale Optimization Conference held at the Center for Applied Optimization, University of Florida, Gainesville in February 1993.

- Pardalos, P.M., D.W. Hearn and W.W. Hager, "Network Optimization," Lecture Notes in Economics and Mathematical Systems, Springer, 1997, ISSN 0075-8442, ISBN 3-560-62541-0.

  This book contains the papers presented at the Network Optimization Conference which was held at the Center for Applied Optimization, University of Florida, Gainesville in February 1996.

Invited Presentations on Optimization Research

- Don Hearn gave invited lectures on *Congestion Toll Pricing for Traffic Networks* at the INFORMS Spring National Meeting and Traffic Networks Models: A Symposium in Honour of Sven Erlander, 1996; on *Solving Congestion Toll Pricing Models* at the INFORMS Fall National Meeting and the C. R. T. Colloquium on Equilibrium and Advanced Transporation Planning, U. of Montreal 1996; and on *Toll Pricing Models for Traffic Networks* at the 8th IFAC Symposium on Transportation Systems, Crete, 1997.

- Panos Pardalos was an invited speaker as follows during March - November, 1996: University of Vienna, Austria; Hungarian Academy of Sciences; University of Puerto-Rico; Technical University of Crete; 8th French-German Colloquium on Optimization, Germany; Linkoping Institute of Technology, Sweden; PARA96 Workshop on Applied Parallel Computing in Industrial problems and Optimization, Denmark; Workshop on Linear Programming, Technical University of Denmark; Oberwolfach, Workshop on Combinatorial Optimization, Germany; and DIMACS Workshop on Hierarchical Structures in Biology. In 1997 he was an invited speaker at IMA, Mathematics in High-Performance Computing; and at the University of Cincinnati.

- William W. Hager presented an invited lecture on *Sup-norm Stability for Control Problems with State Constraints* at the AMS Baton Rouge Meeting, April 1996; on *Stability Analysis for State Constrained Control* at both the SIAM Annual Meeting, Victoria, May 1996, and the SIAM Annual Meeting, St. Louis, July 1996; on *Active Set Strategies and the LP Dual Active Set Algorithm*, INFORMS Conference, Atlanta, October 1996.

- Raphael T. Haftka presented an invited keynote paper *Multidisciplinary Optimization via Response Surface Techniques* at the Israel Conference on Aerospace Sciences, Israel, February 1996; on *ISSMO MicroAV Competition* at the 1st International Conference on Emerging Technologies for Micro Air Vehicles, Atlanta, GA, February 1997; on *Optimization and Experiments – A Survey* at IUTAM Symposium, Kyoto, Japan, August 1996.

- Gang Bao was an invited speaker as follows during 1996: *Direct and Inverse Problems in Micro-Diffractive Optics* at the Mathematics Colloquium, Michigan State University; *Mathematical Modeling of Diffractive Optics* at Bell Labs; *Some Nonlinear Problems in Diffractive Otpics* at International Conference on Dynamical Systems and Differential Equations; *Maxwell's Equations in Periodic Structures*, Mathematics Colloquium, Universite Louis Pasteur, France; *Direct and Inverse Problems in Optical Applications* at the 2nd International Conference on Inverse Problems in Engineering: Theory and Practice, France; *A Multidimensional Hyperbolic Inverse Problem,* Sixth International Conference on Hyperbolic Problems, Hong Kong; *Mathematical Modeling of Diffractive Optics in Peirodic Structures*, '96 Conference on Computational Physics and Applied Mathematics, Beijing, China; *Some Mathematical Problems in Optics*, Math. Colloquium, Harbin Institute of Technology, Harbin, China; *Inverse Problems for Scattering by Periodic Structures* Mathematical Studies of Diffractive Optics at Mathematics Colloquium, Rice University.

- Sherman Bai was an invited speaker as follows during 1996: *Hierarchical Production Scheduling for Manufacturing Systems* at Tsinghua University and also *Competitive and Real-Time Production Scheduling* at the Chinese Academy of Sciences, both in Beijing, China; *Optimal Stochastic Control of a Manufacturing System with Random Breakdowns and Setups* at the INFORMS Meeting, Washington, DC; *Dynamic Setup Scheduling for a Two-Part-Type Stochastic System*, on *Evaluation of Production Control Policies Via Simulation Experimental Design and Analysis,* and *An Optimal Production Flow Control Problem with Piecewise Constant Demand,* both at the 5th IE Research Conference, Minneapolis, MN. During 1997 talks were given on *Optimal Production and Capacity Planning with Piecewise Constant Demand* at the INFORMS Meeting, San Diego; *Production Flow Control for Semiconductor*

Fabrication at Tsinghua University; also *Production Flow Control for Manufacturing Systems* at Beijing Institute of Electronic Systems, at the Shanghai Jiaotong University and at Tongji University all in China.

- Harold Benson gave invited lectures on *Generating the Efficient Outcome Set in Multiple Objective Linear Programs: The Bicriteria Case*; and on *Towards Finding Global Representations of the Efficient Set in Multiple Objective Mathematical Programming* at the INFORMS National Meeting, San Diego, CA, May 1997.

- Bernhard Mair held workshops on *New Statistical Algorithms for Reconstruction of PET Images* at the Workshop on Wavelets and Statistics, Quebec, Canada, April 1996; on *Two Mathematicians, an Engineer and a PET* at University of Minnesota, Oct. 1996; and presented an invited lecture on *Filter Banks and the EM Algorithm* at the IEEE Medical Imaging Conference, Anaheim, CA, Nov. 1996.

- Andrew Vince gave a seminar on *Tableaux and Representations of the Symmetric Group* Spring 1996, at the Combinatorics Seminar held at the University of Florida and held a workshop on *Coxeter Matroids* at the MSRI Workshop on Enumeration and Parially Ordered Sets, Berkeley, CA, 1996.

- David C. Wilson gave seminars on *An Automatic Algorithm for Analysis of 2-D Echocardiographic Short-Axis Images* at both FSU, Feb. 1997, and the *J. of Mathematics and Mathematical Sci. International Conference*, March 1997.

1996-97 Applied Optimization Seminars

Date	Speaker	Title
6/5/96	Carl Modigh M.S. of Engr. Candidate Royal Inst. of Technology, KTH	Local Search Algorithms for the Generation of "D-optimal" Experimental Designs
9/16/96	Richard Francis Professor	Aggregation Error Bounds for a Class of Location Models
9/19/96	Donald Hearn Professor	Research in Applied Optimization
11/14/96	Dr. Motakuri Ramana Visiting Assistant Professor	Modern Optimization via Semi-definite Programming
12/5/96	P.M. Pardalos Professor	Global Optimization: Recent Developments and Research Questions
1/23/97	Leonidas S. Pitsoulis	The Quadratic Assignment Problem
1/30/97	Dr. Sergei Stetsenko	Dual Quadratic Bounds in Polynomial and Boolean Programming
2/6/97	Dr. Motakuri Ramana	Perfect Graphs and Semidefinite Programming
2/13/97	Mehmet B. Yildirim	A New Dominance Rule to Minimize Total Weighted Tardiness on a Single Machine
2/20/97	Dukwon Kim	Special Problems in Nonconvex Minimization
2/27/97	R.A. Murphey	A MultiDimensional Assignment Formulation for a MultiTarget MultiSensor Tracking Problem
3/6/97	Eduardo Pasiliao	Survivable Networks
3/7/97	Jacques Desrosiers GERAD & Ecole des Hautes Etudes Commerciales	Stabilization for Column Generation
3/17/97	Dr. Reiner Horst Chair, Operations Research University of Trier	Optimization of Differences of Two Convex Functions Part I
3/19/97	Dr. Reiner Horst Chair, Operations Research University of Trier	Optimization of Differences of Two Convex Functions Part II

1996-97 Applied Optimization Seminars Cont'd

Date	Speaker	Title
3/24/97	Dr. Reiner Horst Chair, Operations Res. Univ. of Trier	Decomposition Approach for the Global Minimization of Biocave Functions
3/26/97	Dr. Reiner Horst Chair, Operations Res. Univ. of Trier	Utility Function Programs and Optimization Over the Efficient Set in Multiple-Objective
3/31/97	Dr. Reiner Horst Chair, Operations Res. Univ. of Trier	On Global Optimization of Sums of Ratios and the Corresponding Multiple-Criteria Decision Problem
3/27/97	Dr. Tamas Terlaky Faculty of Math. & Inform. Delft Univ. of Technology	An Easy Way to Teach Interior Point Methods
4/10/97	Yasutoshi Yajima Associate Professor Tokyo Inst. of Technology	A Polyhedral Approach for Nonconvex Quadratic Programming Problems with Box Constraints
4/17/97	Yinyu Ye Professor University of Iowa	Approximation Algorithms for Quadratic Programming
5/23/97	Dr. Gilbert Laporte Professor Universite de Montreal	Tour Location Problems

Swedish Exchange Program

The Center administers a program for visiting students from The Royal Institute of Technology (KTH), Stockholm, in cooperation with Ulf Brännlund of the **KTH Division of Optimization and Systems Theory** and E. Rune Lindgren who has joint appointments at KTH and in the UF College of Engineering (AEMES). Since 1990, the Center has hosted KTH students working on optimization and related computational projects at UF.

Also for the first time a second program was administered by the Department of Industrial and Systems Engineering for visiting students from Linköping University.

In both programs each student visits UF for approximately three months and writes a masters thesis under the direction of a UF faculty member. Below is a list of the 1996 students, UF advisors and projects:

The Royal Institute of Technology Students

Student	Professor	Project Title
Espen Kjoelberg	Hearn	A New Heuristic for Multi-Item Lot-Sizing with Polyhedral Optimization
Sten Andersson	Schaub	Calculating Cost of Quality Using Activity Based Coating
Fredrik Lindell	Schaub	Economical Experimental Design
Erik Lundin	Hager	Experimenting with the LP Dual Active Set Algorithm
Nils Lidstrom	Pardalos	A Greedy Randomized Adaptive Search Procedure (GRASP) for the three-index Assignment Problem
Carl Modigh	Schaub	Computer-Generated Experimental Designs for Heteroscedastic Linear Model

Linköping University Students

Student	Professor	Project Title
C.C. Mattson J.F. Gothberg	Francis	Row-Column Demand Point Aggregation for Clustered Data
Anders Bloom	Bai	Using Simulation to Optimize a Production Control Policy

Conference on Optimal Control

February 28 - March 1, 1997

The conference "Optimal Control: Theory, Algorithms, and Applications" was held at the Center for Applied Optimization, University of Florida, February 28–March 1, 1997. The conference was sponsored by the National Science Foundation and was endorsed by the Mathematical Programming Society, by the International Federation for Information Processing (IFIP), and by the International Association for Mathematics and Computers in Simulation (IMACS). The organizers were William Hager, Panos Pardalos, Gang Bao, and Bernard Mair.

The conference brought together 55 researchers from universities, industry, and government laboratories working on the analysis of system stability properties, maximum principles, numerical algorithms, and applications in optimal control. The meeting was organized around the three themes: theory, algorithms, and applications. The first day of the conference focused on stability theory for control systems, beginning with a talk by Irena Lasiecka on control and stabilization of thermoelastic plates governed by linear (small displacement) or nonlinear (large displacement) dynamics subject to appropriate boundary conditions. Uniform decay estimates were established without assuming any mechanical dissipation, the dissipation being due to the release of thermal energy. Important advances in stability theory were also presented by Roberto Triggiani (analyticity of semigroups that arise from thermoelastic plates), Mary Ann Horn (removing geometric constraints in boundary stabilization of elastic systems), Belinda King (reduced basis approach for low order feedback controllers), Christine McMillan (uniform stabilization of cylindrical shells), Yanzhao Cao (exact controllability for parabolic equations), Francesca Bucci (a criterion for uniform asymptotic stability), Richard Datko (stability analysis for functional differential equations using a Poisson integral approach), Mehmet Camurdan (well-posedness of a game theory problem with hyperbolic dynamics), J. E. Masters (stabilization of Maxwell's equations), and Guangcao Ji (stabilization of a plate equation with nonlinear boundary damping).

Also during the first day, there was a session focusing on recent developments for the maximum principle with Hector Sussman discussing nonsmooth systems, Heinz Schaettler examining strong local optimality, and Urszula Ledzewicz presenting a higher order maximum principle. The final session on the first day concerned stability theory in optimal control with Helmut Maurer presenting work on sensitivity for state constrained control problems, and Kazimierz Malanowski analyzing the solution differentiability of control problems with respect parameters; also, Asen Dontchev discussed stability in optimization and connections to stable local convergence of Newton-type methods.

In the second day, the emphasis shifted to algorithms for solving optimal control problems, beginning with a talk by Ekkehard Sachs on trust region methods for constrained parabolic boundary control problems. His approach involved combining a projected Newton scheme with an iterative solver for computing the Newton step. Other algorithmic advances presented throughout the day included work on a Lagrange-Newton method by Fredi Troltzsch, sequential quadratic programming and interior point methods by Matthias Heinkenschloss, augmented Lagragian formulations by Kazi Ito, finite element methods by George Avalos, output least squares by Luther White, the design of stability preserving numerical schemes by Richard Fabiano, multigrid methods by Helmuth Goldberg, and the computation of output feedback gains by a rank minimization algorithm by Friedemann Leibfritz. Also, Boris Mordukhovich showed how intrinsic necessary optimality and controllability conditions for constrained differential inclusions could be obtained by analyzing the limit of discrete approximations.

The final day of the conference focused on a rich array of applications, starting with a talk by Karl-Heinz Hoffmann on the optimal control of superconductors. Other application areas included work on the design of aerospace systems by John Burns, the modeling and identification of polarization in dielectric media by Tom Banks, the optimal control of a flexible arm by Werner Krabs, dynamic multilink structures by Guenter Leugering, biorectors by Suzanne Lenhart, eddy current inspection of corrosion by Fadil Santosa, acoustic flow by Walter Littman, nonlinear optics by Guangye Li, chemical engineering designs by Chris

Floudas, hydropower plants by P. O. Lindberg, thin shells by Michel Delfour, shape optimization by Jan Sokolowski, Stokes' fluid flow by Jainxin Zhou, an industrial furnace by Heidi Jaeger, and the sterilization of canned food by Detlev Kleis.

Participants from Germany, Italy, France, Canada, and Sweden gave the conference an international flavor. Each day of the conference included a lively session of talks by students. A book containing papers emanating from the conference will be published later this year by Kluwer Academic Publishers.

Report on Workshops

Biomedical Image Analysis Teaching Workshop

This workshop was held at the University of Florida Medical School during July 1996. Four talks were given by Professors David C. Wilson, Katherine Schott (Radiology), Christiana Leonard (Neuroscience), and Janice Honeyman (Radiology). The purpose of this workshop was for researchers in mathematics and medicine to get to know one another before the ISTC workshop on July 29-30. Since these gatherings have led to two collaborations and potential for possibly two more, they served their purpose very well. The organizer was David C. Wilson.

Imaging Science Speakers Series Workshop

This workshop was held at the Center for Applied Optimization, University of Florida. This series was organized in cooperation with Chemistry (Weihong Tan) and Physics (Neil Sullivan). The six speakers were nationally known figures in imaging who attracted attendance from across the entire campus. The purpose of the series was to promote contacts and collaborations between UF and other institutions.

Parallel Processing of Discrete Problems Workshop

In the context of the 1996-97 Institute of Mathematics (IMA) special year on high performance computing, this mini-workshop was held at the IMA in Minneapolis, MN on May 12-16, 1997. The workshop featured about 10-15 invited speakers from Europe and North America. The topics discussed covered a wide spectrum of algorithms and applications in parallel processing of discrete optimization and related problems.

Discrete optimization problems arise in various applications such as airline crew scheduling, corporate planning, computer-aided design and manufacturing, communications network design, machine vision, database query design, cellular telephone frequency assignment, and constant directed reasoning. Often, a discrete optimization problem is formulated in terms of finding a least cost solution path in a graph from an initial node to a goal node and solved by graph/tree search methods such as branch-and-bound and dynamic programming.

The search for solutions in a combinatorially large problem space is a major problem in computer science, engineering, and operations research. A general class of difficult and very important combinatorial problems include integer programming with linear or nonlinear objective function. In the worst case, such problems require solution time that grows exponentially as a function of their input size. Consequently, parallel systems, possibly with hundreds or thousands of processors, give us the perspective of efficiently solving relatively large instances of hard problems, being a motivation for using parallel processing.

DIMACS Workshop on Network Design: Connectivity and Facilities Location

This workshop was held at Princeton University on April 28-30, 1997. Organizers were Ding-Zhu Du and Panos Pardalos.

Connectivity and facilities location are two important topics in network designs with applications in data communication, transportation, production planning, and VISI designs. There are two issues concerning these two topics: design and optimization. They involve combinatorial design and combinatorial optimization.

Finding the solution of design problems and the optimal or approximate solution of the related optimization problem are challenging tasks because no polynomial time algorithms are known.

Such problems include some variations of Steiner tree problems (such as multiple connected Steiner network, independent flow problem, and subset-interconnection designs), topology network design, nonlinear assignment problems (such as quadratic assignment problems), problems in facilities location and allocation and network problems appearing in VLSI design. This workshop focused on combinatorial, algorithmic, and applicational aspects of these problems with a special interest in efficient approximation algorithms and their computational performance.

Proceedings of selected refereed papers presented at the workshop will be published at a later date in a book, DIMACS Series, American Mathematical Society.

Other Activities

- P.M. Pardalos was named Associate Editor for the *J. of Combinatorial Optimization* and *J. of Optimization Theory and Applications.* He is a member of the Advisory Board of *OR Transactions.* He was chairman and organizer for the DIMACS workshop on the *Satisfiability (SAT) Problem*, March 11-13, 1996, at Rutgers, University. He also co-organized the Workshop on *Semidefinite Programming and Interior-Point Approaches for Combinatorial Optimization Problems* (with H. Wolforicz) at the FIELDS Institute, May 15-17, 1996.

- D.W. Hearn continues as Associate Editor for *Operations Research* with responsibility for papers on large-scale deterministic optimization and as Associate Editor of *Computational Optimization and Application.* He was named Chair of the Department of Industrial and Systems Engineering, May 1997.

- H. Benson continues as Associate Editor for the *J. of Optimization Theory and Application; Naval Research Logistics*; and *J. of Global Optimization.*

- D.C. Wilson was named Co-Director of the Center for Applied Mathematics. He was organizing chair for the Workshop on *Mathematical Methods in Biomedical Image Analysis,* June 21-22, 1996, San Francisco, CA. He served as editor of a special issue of *Computer Vision and Image Understanding*, in press. He also served as referee for the following: *J. of Mathematical Imaging and Vision*; for *IEEE Transactions on Medical Imaging*; and for *J. of Medical Image Analysis.*

- R.L. Francis was co-recipient, in June, 1996, of the first Lifetime Achievement Award in Location Analysis. The award was given by the Secion on Location Analysis (SOLA) of the Institute for Operations Research and Management Science (INFORMS).

- R.T. Haftka served as graduate coordinator until June 1996. He organized a mini-symposium on Structural Optimization at the IUTAM Congress in Kyoto, Japan, August 1996; is currently organizing first MicroAV competition; he is president of ISSMO and was elected Fellow of the AIAA.

1996-97 Refereed Publications in Optimization

1. Ahn, T. and S.S. Ereng, "Resource Constrained Project Scheduling Problem with Multiple Crashable Models: A Heuristic Procedure, *European J. of Operational Research*, in press.

2. Anderson, G., R.L. Francis, T. Normark, and M.B. Rayco, "Aggregation Methods for Large-Scale Network Location Problems, *Proceedings on the Seventh Int'l Symposium on Location, ISOLDE*, in press.

3. Anderson, J.M.M, B.A. Mair, M. Rao and C.H. Wu, "A Weighted Least Squares Method," *Conference Record of 1995 IEEE Medical Imaging Conference,* 2 (1996) 1292-1296.

4. Bai, S.X., M. El "Transient and Steady State Analysis of a Manufacturing System with Dynamic Setup Changes," *Global Optimization*, 8 (1996) 349-378.

5. Bai, S. X. and J. H. Burhanpurwala,"Hierarchical Production Control for a Manufacturing System with Dynamic Setup Changes," *OR Spektrum*, 18 (1996) 81-96.

6. Bai, S. X. "A Note on Determining Pure-Strategy Equilibrium Points of Bimatrix Games," *Computer and Mathematics with Applications*, 32(7) (1996) 29-35.

7. Bai, S. X. and S. Varanasi,"An Optimal Production Flow Control Problem with Piecewise Constant Demand," *Computer and Mathematical Modeling*, 24(7) (1996) 87-107.

8. Bai, S. X. and S. B. Gershwin, "Scheduling Manufacturing Systems with Work-In-Process Inventory Control: Reentrant Systems," *OR Spektrum*, 18 (1996) 187-195.

9. Bai, S.X,. "Competitive Production Scheduling: A Two-Firm, Noncooperative Dynamic Game," *Annals of Operations Research*, 68 (1996) 3-31.

10. Bai, S.X., Y.-K. Tsai, M. El Hafsi, and K. Deng, "Production Scheduling in a Price Competition," *Computer and Mathematics with Applications*, 33(5) (1997) 5-19.

11. Bai, S.X., "Competitive Production Scheduling: A Two-Firm Noncooperative Finite Dynamic," *Annals of Operations Research,* in press.

12. Balabanov, V.O., and R.T. Haftka, "Topology Optimization of Transport Wing Internal Structure," *J. of Aircraft,* 33 (1) 232-233, 1996.

13. Balabanov, V., M. Kaufman, A.A. Giunta, R.T. Haftka, B. Grossman, W.H. Mason and L.T. Watson, "Developing Customized Wing Weight Function by Structural Optimization on Parallel Computers," *Proceedings of the 37th AIAA/ASME/ASCE/AHS Structures, Structural Dynamics and Material Conference, Part 1, AIAA Paper 96-1336*, (1996) 113-125.

14. Balabanov, V., M. Kaufman, D.L. Knill, D. Haim, O. Golovidov, A.A. Giunta, B. Grossman, W.H. Mason, L.T. Watson and R.T. Haftka, "Dependence of Optimal Structural Weight on Aerodynamics Shape for a High-Speed Civil Transport," 6th AIAA/NASA/USAF/ISSMO Symposium on Multidisciplinary Analysis and Optimization, (1996) *AIAA Paper 96-4046.*

15. Bao, G., "Inverse problems in partial differential equations", "Numerical Methods in Applied Sciences", ed. by W. Cai, Z. Shi, C-W. Shu, and J. Xu, Science Press, New York, 20-38, 1996.

16. Bao, G. and W.W. Symes, "Computation of pseudo-differential operators", SIAM J. Sci. Comput., Vol. 17, No. 2 (1996), 416-429.

17. Bao, G. and W.W. Symes, "On the sensitivity of solutions of hyperbolic equations to the coefficients", Comm. in P.D.E., 21(3&4) (1996), 395-422.

18. Bao, G., "Numerical analysis of diffraction by periodic structures: TM polarization", Numerische Mathematik **75** (1996), 1-16.

19. Bao, G., "Variational approximation of Maxwell's equations in biperiodic structures", SIAM J. Appl. Math., to appear.

20. Bao, G. and Y. Chen, "A nonlinear grating problem in diffractive optics", SIAM J. Math. Anal., to appear.

21. Bao, G. and Z. Zhou, "Inverse diffraction by a doubly periodic structure", C.R. Acad. Sci. Paris, Série I, to appear.

22. Bao, G., "Smoothness of coefficients and boundary values for the wave equation", SIAM J. Math. Anal., to appear.

23. Bao, G., "Inverse diffraction by a periodic perfect conductor with several measurements", in the Proceedings of ASME, to appear.

24. Bao, G. and W.W. Symes, "Regularity of an inverse problem in wave propagation", in "Inverse problems of Wave Propagation and Diffraction", ed. by G. Chavent and P. Sabatier, Springer-Verlag, to appear.

25. Bao, G., "Mathematical modeling of nonlinear diffractive optics", in the Proceedings of International Conference on Dynamical Systems and Differential Equations, to appear.

26. Benson, H.P. and G.M. Boger, "Multiplicative Programming Problems: Analysis and an Efficient Point Search Heuristic," *J. of Optimization Theory & Applications*, in press.

27. Benson, H.P., D. Lee, and J.P. McClure "A Multiple-objective Linear Programming Model for the Citrus Rootstock Selection Problem in Florida," *J. of Multi-Criteria Decision Analysis*, in press.

28. Benson, H.P. "Generating the Efficient Outcome Set in Multiple Objective Linear Programs: The Bicriteria Case," *Acta Mathematica Vietnamica*, in press.

29. Benson, H.P. and S. Sayin, "Towards Finding Global Representations of Efficient Sets in Multiple Objective Mathematical Programming," *Naval Research Logistics*, 44 (1997) 47-67.

30. Benson, H.P., "Deterministic Algorithms for Constrained Concave Minimization: A Unified Critical Survey," *Naval Research Logistics*, 43 (1996) 765-795.

31. Benson, H.P., and D. Lee, "An Outcome-Based Algorithm for Optimizing over the Efficient Set of a Bicriteria Linear Programming Problem," *J. of Optimization Theory and Applications*, 88 (1996) 77-105.

32. Bergendor, P., D.W. Hearn and M.V. Ramana, "Congestion Toll Pricing of Traffic Networks," *Network Optimization*, Springer-Verlag series *Lecture Notes in Economics and Mathematical Systems.* 450 (1997) 51-71.

33. Bharara, A., and C.-Y. Lee, "Implementation of an Activity-Based Costing System in a Small Manufacturing Company," *Intl. J. of Production Research,* in press.

34. Bomze, I., P.M. Pardalos, T. Csendes and R. Horst, "Developments in Global Optimization," Kluwer, (1997).

35. Burgee, S., A.A. Giunta, R. Narducci, L.T. Watson, B. Grossman and R.T. Haftka, "A Coarse Grained Parallel Variable-Complexity Multidisciplinary Optimization Paradigm," *The Int'l J. of Supercomputer Applications and High Performance Computing*, 10(4) (1996) 269-299.

36. Chrisfulli, P.J., M. Kaufman, A.A. Giunta, W.H. Mason, B. Grossman, L.T. Watson and R.T. Haftka, "Response Surface Approximation for Pitching Moment, Including Pitch-Up, in the MDO Design of an HSCT," 6th AIAA/NASA/USAF/ISSMO Symposium on Multidisciplinary Analysis and Optimization, (1996) *AIAA Paper 96-4136.*

37. Cudney, H.H., R.T. Haftka, G. Magalaras, E. Nikolaidis and E. Ponslet, "Comparison of Probabilistic and Deterministic Optimization using Genetic Algorithm," *Structural Optimization,* in press.

38. Crisalle, O. D. and R. K. Ballamudi, "Robust Pole-Placement Technique for Plants with Ellipsoidally Uncertain Parameters," *Chemical Engineering Science*, 1996, in press.

39. Denizel-Sivri, M. and S.S. Erenguc, "Exact Solution Procedures for a Class of Production Planning Problems in Flexible Manufacturing Systems," *Computers and Operations Research*, in press.

40. Denizel, M., S. Erenguc and H.P. Benson, "Dynamic Lot-Sizing with Setup Cost Reduction," *European J. of Operational Research*, in press.

41. Denizel-Sivri, M., S.S. Erenguc and S. Hanif, "Convex Envelop Results and Strong Formulations for a Class of Integer and Mixed Integer Problems," *Naval Research Logistics*, 43(4) (1996) 503-518.

42. Dey, A.K., B.A. Mair and F.H. Ruymgaart, "Cross-validation for Parameter Selection in Inverse Estimation Problems," *Scandinavian J. of Statistics,* 23 (1996) 609-620.

43. DingZhu D., J. Gu and P.M. Pardalos, "Satisfiability Problems," *DIMACS Series*, American Mathematical Society, in press.

44. DingZhu D. and P.M. Pardalos, "Network Design: Connectivity and Facilities Location," *DIMACS Series*, American Mathematical Society, in press.

45. Dontchev, A.L. and W.W. Hager, "Lipschitzian Stability for State Constrained Nonlinear Optimal Control," *SIAM Journal on Control and Optimization,* in press.

46. Dontchev. A.L. and W.W. Hager, "Implicit Functions Defined by Generalized Equation," *World Congress of Nonlinear Analysts '92*, Walter de Gruyter, Berlin, New York, (1996) 2289-2298.

47. El Hafsi, M. and S. X. Bai, "Optimal Production Control of a Dynamic Two-Product Manufacturing System with Setup Costs and Setup Times," *Global Optimization,* 9 (1996) 183-216.

48. El Hafsi, M. and S. X. Bai, "Optimal Production and Setup Control of a Dynamic Two-Product Manufacturing System: Analytical Solution," *Computer and Mathematics with Applications,* 24(3) (1996) 57-78.

49. El Hafsi, M. and S. X. Bai, "The Common Cycle Economic Lot Scheduling Problem with Backorders: Benefits of Controllable Production Rates," *Global Optimization,* 10(3), (1997).

50. Francis, R.L., T. J. Lowe and M. B. Rayco, "Row-Column Aggregation for Rectilinear Distance p-Median Problems," *Transportation Science,* 30(2) May 1996.

51. Furuya, H. and R.T. Haftka, "Placing Actuators on Space Structures by Genetic Algorithms and Effectiveness Indices," *Structural Optimization,* in press.

52. Furuya, H. and R.T. Haftka, "Combining Genetic and Deterministic Algorithms for Locating Actuators on Space Structures," *J. of Spacecraft and Rockets*, 33(3) (1996) 422-427.

53. Garcelon, J., R. Haftka and S. Scotti, "Approximation in Optimization and Damage Tolerant Design, *Proceedings of the 38th AIAA/ASME/ASCE/ AHS/ASC Structures, Structural Dynamics and Material Conference*, *Part 2*, *AIAA Paper 97-1050*, (1997) 1193-1203.

54. Garcia-Rubio, Luis, Mark E. Orazem, and Oscar D. Crisalle, "Chemometrics Techniques and Particle Characterization," *Proceedings of the Fifth World Congress of Chemical Engineering*, San Diego, CA, July 1996, in press.

55. Geiser, E.A., D.D. Buss, J.H. Wible, Jr., D.C. Wilson, M.S. Cunningham, A.L. Webb, D.C. Wilson, D.C., and M. Yang, "Evidence for a Relation Between Inspired Gas Mixture and the Left Ventricular Contrast Achieved with Albunex in a Canine Model, Clinical Cardiology, 19 (1996) 289-295.

56. Gibbons, L.E., D.W. Hearn, P.M. Pardalos and M.V. Ramana, "Continuous Characterizations of the Maximum Clique Problem," *Mathematics of Operations Research*, (1997) in press.

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58. Giunta, A.A., V. Balabanov, D. Haim, B. Grossman, W.H. Mason, L.T. Watson and R.T. Haftka, "Aircraft Multidisciplinary Design Optimisation Using Design of Experiments Theory and Response Surface Modelling," *Aeronautical Journal*, Paper No. 2260, in press.

59. Giunta, A.A., V. Balabanov, M. Kaufman, S. Burgee, B. Grossman, R.T. Haftka, W.H. Mason, L.T. Watson, "Variable Complexity Aerodynamic-Structural Optimization via Response Surface Techniques," Multidisciplinary Design Optimization, N.M. Alexandrov and M.Y. Hussaini (Eds.), *Proceedings of ICASE/LaRC Workshop on Multidisciplinary Design Optimization*, SIAM, Philadelphia, (1997) 348-367.

60. Giunta, A.A., V. Balabanov, D. Haim, B. Grossman, W.H. Mason, L.T. Watson and R.T. Haftka, "Wing Design for a High-Speed Civil Transport Using Design of Experiments Methodology," *6th AIAA/NASA/USA/USAF/ ISSMO Symposium on Multidisciplinary Analysis and Optimization*, (1996) *AIAA Paper 96-4001.*

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62. Hearn, D.W. and M. Ramana, "Solving Congestion Toll Pricing Models," to appear in *Equilibrium and Advanced Transportation Modeling*, P. Marcotte and S. Nguyen (Eds.), Kluwer Academic Publishers, 1997, 20 pp.

63. Hearn, D.W. and M. Ramana, "Toll Pricing Models for Traffic Networks," *Proceedings of 8th IFAC Symposium on Transportation Systems*, Chania, Greece, June 16-18, 1997, in press.

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