This research effort resulted in 50 research publications, 4 related published books, 10 PhD students produced, and 13 postdoctoral researchers supported (one of whom, Yuying Li, won the 6th FOX prize competition).

Our work under this support broadly falls into five categories: automatic differentiation, sparsity, constraints, parallel computation, and applications.

**Automatic Differentiation (AD):** We developed strong practical methods for computing sparse Jacobian and Hessian matrices which arise frequently in large scale optimization problems [10,35]. In addition, we developed a novel view of “structure” in applied problems along with AD techniques that allowed for the efficient application of sparse AD techniques to dense, but structured, problems [4,5,9,37,40,41]. Our AD work included development of freely available MATLAB AD software [5].

**Sparsity:** We developed new effective and practical techniques for exploiting sparsity when solving a variety of optimization problems. These problems include: bound constrained problems, robust regression problems, the null space problem, and sparse orthogonal factorization [8,13,16,18,21,22,28,29,32,33,34,35,38,39,42,47,48]. Our sparsity work included development of freely available and published software [38,39].

**Constraints:** Effectively handling constraints in large scale optimization remains a challenge. We developed a number of new approaches to constrained problems [2,3,6,12,24,26,36] with emphasis on trust region methodologies.

**Parallel Computation:** Our work included the development of specifically parallel techniques for the linear algebra tasks underpinning optimization algorithms. Our work contributed to the nonlinear least-squares problem, nonlinear equations, triangular systems, orthogonalization, and linear programming [23,25,27,30,38,39,45,49,50].

**Applications:** Our optimization work is broadly applicable across numerous application domains. Nevertheless we have specifically worked in several application areas including molecular conformation, molecular energy minimization, computational finance, and bone remodeling [1,11,14,15,17,19,20].

We conclude by mentioning that our PhD students have gone to major industry and government labs (such as Sandia), as well as major universities (such as Purdue), and the mathematical software industry more broadly (such as Mathworks, Bloomberg).
Research Refereed Journal Publications under this support


**Other Published Research Publications under this support**


**Related Books Published in this Period**


PhD Students under this support

1. Adrian Mariano, *Image Processing with Total Variation Minimization*, Center for Applied Mathematics (May, 1999)


Postdoctoral Researchers (partially) supported under this grant

1. Jacqueline Huang (Johns Hopkins), 1999 – 200
3. Jean-François Pusztaszeri (CERN, Switzerland), 1997 -- 1998
5. Ai-ping Liao (Cornell, ORIE), 1992 -- 1995
6. Chunguang Sun (Penn State), 1991 -- 1994
7. Li-zhi Liao (Cornell, ORIE), 1992 -- 1994
8. Shirish Chinchalkar (Cornell, MAE), 1991 -- 1993
9. Zhijun Wu (Rice), 1991 -- 1993
13. Guangye Li (Rice), 1986 -- 1988
In general, global numerical optimization problem can be expressed as follows (without loss of generality minimization problem is considered here): where \( f \) is the objective function, \( x_i \) are the lower and upper bounds for each decision variable, respectively. The optimization of the large scale problems of this kind (i.e., \( \geq 1 \)) is considered a challenging task since the solution space of a problem often increases exponentially with the problem dimension and the characteristics of a problem may change with the scale [1]. Generally speaking, there are different types of real-world large scale global optimization (LSGO) problems in engineering, manufacturing, and economy applications (biocomputing, data or web mining, scheduling, vehicle routing, etc.).