Research in Optimization and Game-theory

Main Research Thrusts: Prof. Uday V. Shanbhag

- Nonlinear programming
- Game theory
- Risk-averse optimization and games
- Design and operation of electricity markets

Research in Optimization and Game-theory

Main Research Thrusts: Prof. Uday V. Shanbhag

- **Nonlinear Programming (NLPs)**
  - Ill-posedness
  - Uncertainty
    - Scalable, convergent algorithms
    - Monte-Carlo sampling methods
  - Second-order KKT points
  - Distributed convex optimization
    - Convergence properties
    - Error analysis
- **Game Theory**
  - Properties of Nash equilibrium problems with shared constraints
  - Stochastic Nash games
    - Properties
    - Scalable convergent algorithms (matrix splitting, projection schemes)
  - Nash-Stackelberg equilibrum problems

Research in Optimization and Game-theory

Main Research Thrusts: Prof. Uday V. Shanbhag

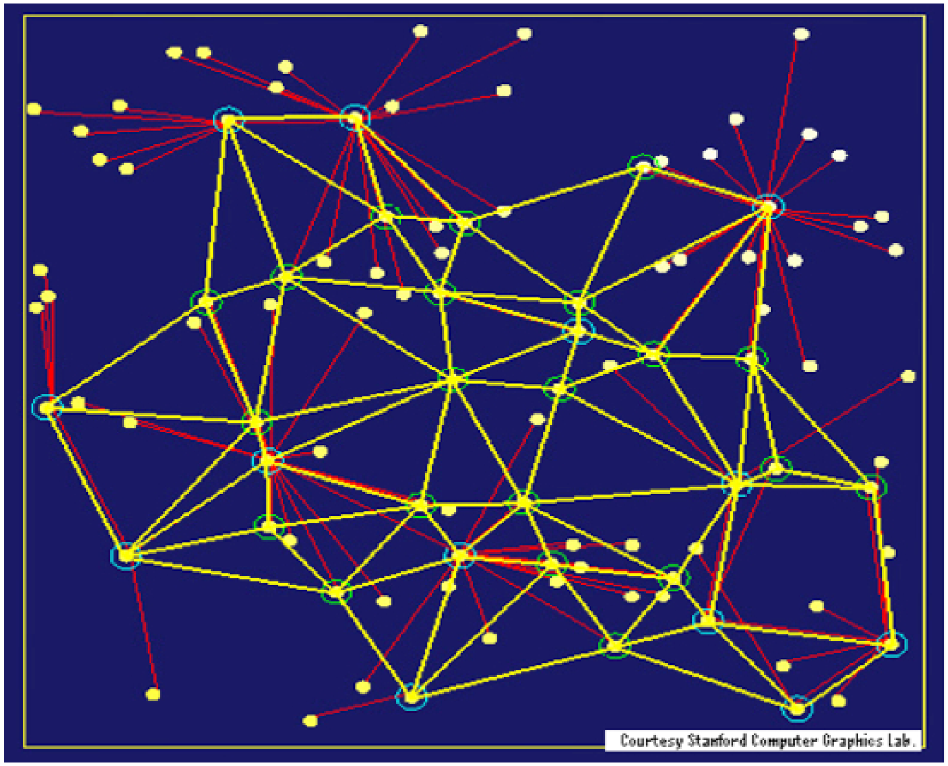
- Risk-averse Optimization and Games
  - Coherent risk-measures, particularly Conditional Value-at-Risk (CVaR)
  - Optimization with risk-measures
    - Sampling methods with bounds
    - Smoothing schemes
  - Risk-averse Nash games
    - Properties
    - Algorithms
      - Smoothing schemes
      - Sampling methods
- Design / operations in Electricity Markets
  - Two-period contracting models
    - Forward / spot-market bidding, properties, algorithms
  - Bidding with risky assets (integrating wind producers)
    - Risk-averse games
    - Coupled markets
    - Market design, algorithms

Research in Distributed Optimization and Duality
Main Research Thrusts: Prof. Angelia Nedich

- **Distributed Optimization**
- **Convex and Non-Convex Optimization**
- **Non-Differentiable and Stochastic Optimization**
  - Large scale problems
  - Globally optimal and near optimal solutions
  - Trade-off between accuracy and convergence time
- **Applications currently in networked systems**
  - Sensor networks
  - Communication networks
  - Social networks

Research in Distributed Network Optimization
Professor Angelia Nedich

- **Distributed Optimization**
  - In network optimization
  - Local computations and information exchange
  - In the presence of uncertainties
    - Noisy communications
    - Link/node failures
  - Algorithm design and performance analysis



The RoboMote: A platform for research in robotic sensor networks.
Credit: USC Robotic Embedded Systems Lab (PI: Prof. Gaurav S. Sukhatme)

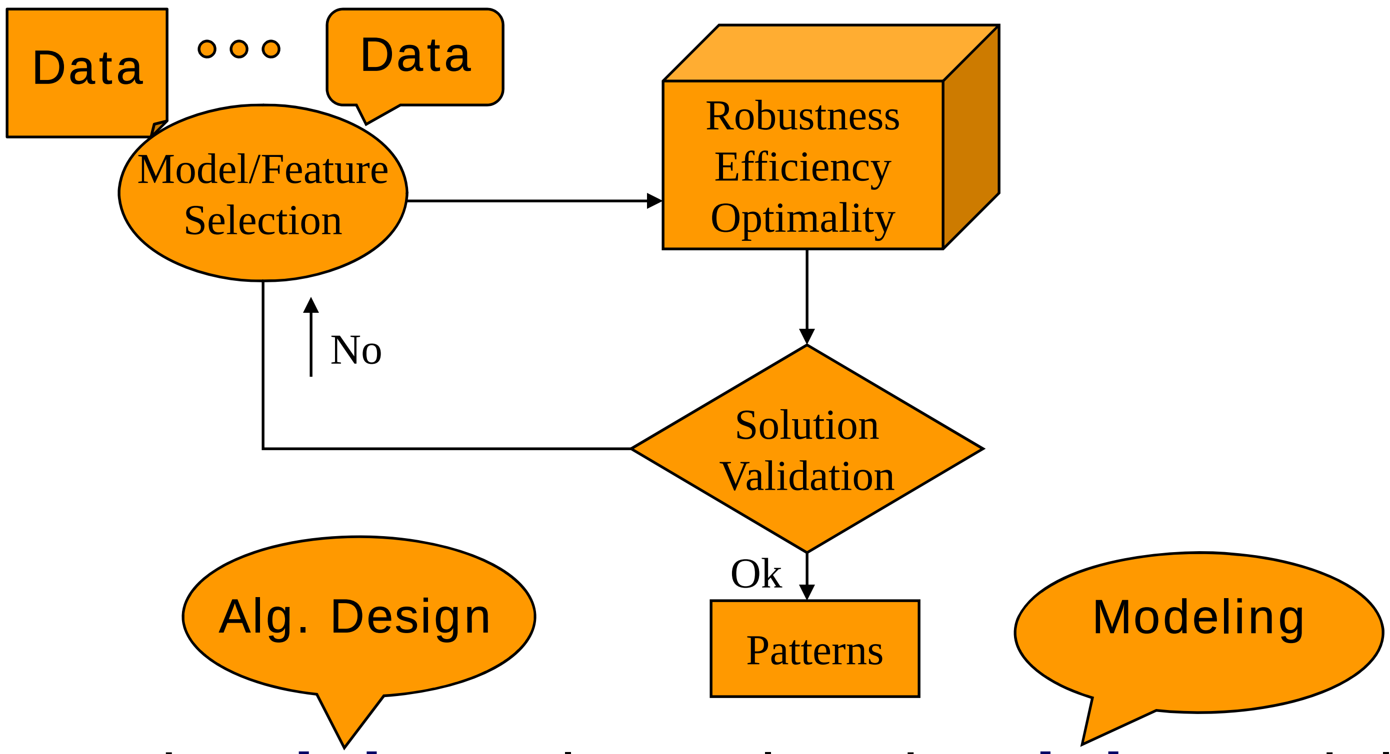
Research in Optimization and Stochastic Approx.
Professor Angelia Nedich

- **Duality in Convex and Non-Convex Optimization**
- **Non-Differentiable Optimization**
  - Development of (non)convex duality framework
  - Algorithmic development based on primal-dual approaches
- **Stochastic Optimization**
  - Resource allocation policies for users in wireless networks

Optimization Modeling and Algorithm Design

Main Research Thrusts: Prof. Jiming Peng

- **The role of optimization in a discovery process**



- Use the **right** tool to solve the **right** model for the **right** patterns

Research in Optimization and Equilibria

Main Research Thrusts: Professor Jong-Shi Pang

- **Global optimization of complementary convex programs**
  - A complementary convex program (CCP) is a very challenging constrained optimization problem which is almost a convex program except for a special disjunctive constraint. A major source of a CCP occurs in *bi-level* or *inverse convex programming* that includes the problem of *parameter identification* in convex minimization. Our research focuses on the development of efficient algorithms to compute a globally optimal solution to a CCP if it exists and to provide a certificate otherwise. *Hierarchical decision making* and cross validation in data mining are two areas where the methodology is currently being applied.

- **Computation of engineering and economic equilibria**
  - Equilibrium is a pervasive phenomenon in engineering and economics. The fundamental economic principle of supply balancing demand is a simple example of a market system in equilibrium. The resolution of conflicts among multiple agents with selfish objectives requires the notion of an equilibrium of a *game*. Our research focuses on the modeling, computation, and analysis of equilibrium problems arising from complex engineering and economics systems such as, *electricity markets, communication networks, supply chains, oligopolistic production systems,* and *transportation*.

Research in Optimization and Equilibria (cont.)
Professor Jong-Shi Pang

- **Differential variational systems**
  - Combining an ordinary differential equation with a finite-dimensional variational condition, a differential variational system is a novel mathematical paradigm that provides a broad framework for the modeling of complex *dynamical systems* containing unilateral constraints (in the form of algebraic inequalities) and disjunctions (yielding mode switches and state discontinuities). Our research focuses on the analysis and control of such non-traditional dynamical systems and their optimization as well as applications to *differential Nash games, frictional contact problem,* and *dynamic traffic equilibrium problems*.

- **Computational financial engineering**
  - *Financial engineering* is a new discipline that pertains to the application of mathematical theory and engineering methods to the solution of financial decision making problems. *Portfolio selection* and *option pricing* are two areas in financial engineering that require extensive optimization techniques and related numerical methods. The proper quantification of *risk* is an important first step in formulating and solving a financial optimization problem. The pricing of *exotic* (such as *American*) *options* and the inverse computation of *implied volatilities* from computed model prices are examples of research topics of interest to us.

Research in Optimization and Equilibria (cont.)
Recent publications of Professor Jong-Shi Pang:

- **Books**

R.W. Cottle, J.S. Pang, and R.E. Stone, *The Linear Complementarity Problem*. Academic Press, Boston (1992): winner of the 1994 Frederick W. Lanchester Prize awarded by INFORMS.

Z.Q. Luo, J.S. Pang, and D. Ralph, *Mathematical Programs With Equilibrium Constraints*. Cambridge University Press, Cambridge, England (1996).

F. Facchinei and J.S. Pang, *Finite-Dimensional Variational Inequalities and Complementarity Problems*, Volumes I and II. Springer-Verlag, New York (2003).

- **Global optimization of complementary convex programs**

J. Hu, J.E. Mitchell, and J.S. Pang, An LPCC approach to nonconvex quadratic programs, *Mathematical Programming,* revision under review.

J. Hu, J.E. Mitchell, J.S. Pang, K. Bennett, and G. Kunapuli, On the global solution of linear programs with linear complementarity constraints, *SIAM Journal on Optimization*, 19 (2008) 445--471.

J.S. Pang and S. Leyffer, On the global minimization of the value-at-risk, *Optimization Methods and Software* 19 (2004) 611—631.

Recent publications of Jong-Shi Pang (cont.)

- ***Computation of engineering and economic equilibria***

G. G\"urkan, Approximations of Nash equilibria, *Mathematical Programming, Series B* 117 (2009) 223—253.

B.F. Hobbs and J.S. Pang, Nash-Cournot equilibria in electric power markets with piecewise linear demand functions and joint constraints, *Operations Research* 55 (2007) 113--127.

F. Facchinei and J.S. Pang, Nash equilibria: The variational approach. In Y. Eldar and D. Palomar, editors, *Convex Optimization in Signal Processing and Communications*. Cambridge University press (Cambridge 2009).

- **Differential variational systems**

J.S. Pang and D.E. Stewart, Differential variational inequalities, *Mathematical Programming* 113 (2008) 345—424.

K. Camlibel, J.S. Pang, and J.L. Shen, Conewise linear systems, *SIAM Journal on Control and Optimization* 45 (2006) 1769--1800.

L. Han and J.S. Pang, Non-Zenoness of a class of differential quasi-variational inequalities, *Mathematical Programming, Series A online* DOI 10.1007/s10107-008-0230-0.

Recent publications of Jong-Shi Pang (cont.)

- **Computational financial engineering**

J. Huang and J.S. Pang, A mathematical programming with equilibrium constraints approach to inverse pricing of American options: the case of an implied volatility surface, *The Journal of Computational Finance* 4 (2000) 21—56.

J. Huang and J.S. Pang, Option pricing and linear complementarity, *The Journal of Computational Finance* 2 (1998) 31—60.

- **Data mining, communication games, and others**

J.S. Pang, Frictional contact models with local compliance: Semismooth formulation. *Zeitschrift fur Angewandte Mathematik und Mechanik* 88 (2008) 454—471.

G. Kunapuli, K. Bennett, J.S. Pang, and J. Hu, Classification model selection via bilevel programming, *Optimization Methods and Software* 23 (2008) 475—489.

J.S. Pang, A. Scutari, F. Facchinei, and C. Wang, Distributed power allocation with rate constraints in Gaussian frequency-selective channels, *IEEE Transactions on Information Theory* 54 (2008) 3471—3489.

Research support and team members

- **National Science Foundation**
  - Operations Research Program
  - Applied and Computational Mathematics Program
- **Office of Naval Research**
  - Operations Research Program
- **Air Force Office of Sponsored Research**
  - Optimization and Discrete Mathematics program
- **Ph.D. students**
  - Yu-ching Lee
  - Alok Tiwari
- **Many US and international collaborators**

Please visit http://www.iese.uiuc.edu/research/faculty/pang.html for more information.

Optimization Modeling and Algorithm Design

Main Research Thrusts: Prof. Jiming Peng

0-1 conic optimization, modeling and approximation

- The 0-1 conic optimization model is a natural extension of the classical integer programming to the setting of conic constraints. Many challenging mixed integer nonlinear optimization problems from various domains such as data mining and communication can be embedded into this model, which can be relaxed to polynomial solvable conic optimization problems. Our research focuses on the development of scalable and effective approximation algorithms for this new class of problems, with specifications to applications from data mining.
- J. Peng and Y. Wei, **Approximating K-means-type clustering via semidefinite programming (SDP)**. *SIAM J. Optimization. 18 (2007), no. 1, 186--205.*
- V. Singh, L. Mukherjee, J. Peng, J. Xu**, Ensemble Clustering using SDP**, *Proceedings of Advances in Neural Information Processing Systems (NIPS), December, 2007.*
- H.R. Chen and J. Peng, **0-1 SDP for Graph-Cut Clustering: Modeling and Approximation,** *Invited paper, to appear in CRM Proceedings & Lecture Notes of the American Mathematical Society, 2008.*

Optimization Modeling and Algorithm Design

Main Research Thrusts: Prof. Jiming Peng

- **Data-driven approaches for binary and non-convex quadratic programming**
  - Binary and non-convex QPs arise from various disciplines and are among the hardest optimization problems. In this study, we explore the data structure in the input data to develop good approximations to the original hard problems, and investigate conditions under which the underlying problem is polynomial solvable.
  - H. Mittelmann, X. Li and J. Peng. **New convex Relaxations for Quadratic Assignment Problems.** Submitted, *2008*.
  - H. Mittelmann and J. Peng. **Estimating Bounds for Quadratic Assignment Problems Associated with Hamming and Manhattan Distance Matrices based on SDP**, *Submitted. 2007.*
  - X. Li, J. Peng and R. Yang, **A data driven SDP approach to binary QP.** *Submitted , 2009.*