RESEARCH REPORT
Optimization
Computation for design and optimization * computational engineering * humans and automation * operations research * evolutionary design and optimization * aerospace computational design * mixed-integer linear programming
Brief Overview of Research: Optimization

This report by MIT’s Industrial Liaison Program identifies selected MIT research in the area of optimization. For more information, please contact MIT’s Industrial Liaison Program at +1-617-253-2691.

<table>
<thead>
<tr>
<th>OPTIMIZATION</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPERATIONS RESEARCH CENTER (ORC)</td>
<td>4</td>
</tr>
<tr>
<td>COMPUTATION FOR DESIGN AND OPTIMIZATION (CDO) PROGRAM</td>
<td>5</td>
</tr>
<tr>
<td>MIT CENTER FOR COMPUTATIONAL ENGINEERING (CCE)</td>
<td>6</td>
</tr>
<tr>
<td>COMPUTATIONAL ENGINEERING (CE)</td>
<td>6</td>
</tr>
<tr>
<td>AEROSPACE COMPUTATIONAL DESIGN LABORATORY (ACDL)</td>
<td>8</td>
</tr>
<tr>
<td>EVOLUTIONARY DESIGN AND OPTIMIZATION GROUP (EVO-DESIGNOPT)</td>
<td>8</td>
</tr>
<tr>
<td>HUMANS AND AUTOMATION LAB (HAL)</td>
<td>9</td>
</tr>
<tr>
<td>AERONAUTICS AND ASTRONAUTICS</td>
<td>9</td>
</tr>
<tr>
<td>DAVID L. DARMOFAL</td>
<td>9</td>
</tr>
<tr>
<td>OLIVIER L. DE WECK</td>
<td>10</td>
</tr>
<tr>
<td>Multidisciplinary Design Optimization</td>
<td>10</td>
</tr>
<tr>
<td>EMILIO FRAZZOLI</td>
<td>10</td>
</tr>
<tr>
<td>JONATHAN P HOW</td>
<td>11</td>
</tr>
<tr>
<td>Flight Experiments Using Mixed-Integer Linear Programming (MILP) Trajectory Optimization</td>
<td>11</td>
</tr>
<tr>
<td>AMEDEO R. ODONI</td>
<td>11</td>
</tr>
<tr>
<td>JAIME PERAIRE</td>
<td>12</td>
</tr>
<tr>
<td>RAUL RADOVITZKY</td>
<td>12</td>
</tr>
<tr>
<td>KAREN E. WILLCOX</td>
<td>12</td>
</tr>
<tr>
<td>BRIAN C. WILLIAMS</td>
<td>12</td>
</tr>
<tr>
<td>CHEMICAL ENGINEERING</td>
<td>13</td>
</tr>
<tr>
<td>PAUL I. BARTON</td>
<td>13</td>
</tr>
<tr>
<td>WILLIAM H. GREEN</td>
<td>13</td>
</tr>
<tr>
<td>CIVIL AND ENVIRONMENTAL ENGINEERING</td>
<td>13</td>
</tr>
<tr>
<td>CYNTHIA BARNHART</td>
<td>13</td>
</tr>
<tr>
<td>MARKUS J. BUHELER</td>
<td>14</td>
</tr>
<tr>
<td>PATRICK JAILLET</td>
<td>14</td>
</tr>
<tr>
<td>DAVID SIMCHI-LEVl</td>
<td>14</td>
</tr>
<tr>
<td>ECONOMICS</td>
<td>15</td>
</tr>
<tr>
<td>IVAN WERNING</td>
<td>15</td>
</tr>
<tr>
<td>ELECTRICAL ENGINEERING AND COMPUTER SCIENCE</td>
<td>15</td>
</tr>
<tr>
<td>DIMITRI P. BERTSEKAS</td>
<td>15</td>
</tr>
</tbody>
</table>
### Optimization

<table>
<thead>
<tr>
<th>Author</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Munther A. Dahleh</td>
<td>15</td>
</tr>
<tr>
<td>Luca Daniel</td>
<td>16</td>
</tr>
<tr>
<td>Peter L. Hagelstein</td>
<td>16</td>
</tr>
<tr>
<td>Thomas L. Magnanti</td>
<td>16</td>
</tr>
</tbody>
</table>

**Network Design and Optimization**

<table>
<thead>
<tr>
<th>Author</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alexandre Megretski</td>
<td>17</td>
</tr>
<tr>
<td>Sanjoy K. Mitter</td>
<td>17</td>
</tr>
<tr>
<td>Una May O’Reilly</td>
<td>17</td>
</tr>
<tr>
<td>Asuman E. Ozdaglar</td>
<td>17</td>
</tr>
<tr>
<td>Pablo A. Parrilo</td>
<td>18</td>
</tr>
<tr>
<td>Devavrat Shah</td>
<td>18</td>
</tr>
<tr>
<td>Vladimir Stojanovic</td>
<td>18</td>
</tr>
<tr>
<td>John N. Tsitsiklis</td>
<td>18</td>
</tr>
<tr>
<td>George C. Verghese</td>
<td>19</td>
</tr>
<tr>
<td>Jacob K. White</td>
<td>19</td>
</tr>
</tbody>
</table>

### Materials Science and Engineering

<table>
<thead>
<tr>
<th>Author</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joel P. Clark</td>
<td>19</td>
</tr>
</tbody>
</table>

### Mathematics

<table>
<thead>
<tr>
<th>Author</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alan Edelman</td>
<td>20</td>
</tr>
<tr>
<td>Michel X. Goemans</td>
<td>20</td>
</tr>
<tr>
<td>Benjamin Seibold</td>
<td>20</td>
</tr>
<tr>
<td>Peter W. Shor</td>
<td>21</td>
</tr>
</tbody>
</table>

### Mechanical Engineering

<table>
<thead>
<tr>
<th>Author</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rohan Abeyaratne</td>
<td>21</td>
</tr>
<tr>
<td>Daniel D. Frey</td>
<td>21</td>
</tr>
<tr>
<td>David C. Gossard</td>
<td>21</td>
</tr>
<tr>
<td>Nicolas G. Hadjiconstantinou</td>
<td>22</td>
</tr>
<tr>
<td>Alexander Mitsos</td>
<td>22</td>
</tr>
</tbody>
</table>

**Optimization Algorithms**

<table>
<thead>
<tr>
<th>Author</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthony T. Patera</td>
<td>22</td>
</tr>
<tr>
<td>Nicholas M. Patrikalakis</td>
<td>23</td>
</tr>
<tr>
<td>James C. Preisig</td>
<td>23</td>
</tr>
<tr>
<td>Sanjay E. Sarma</td>
<td>23</td>
</tr>
</tbody>
</table>

### Sloan School of Management

<table>
<thead>
<tr>
<th>Author</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimitris J. Bertsimas</td>
<td>24</td>
</tr>
<tr>
<td>Vivek F. Farias</td>
<td>24</td>
</tr>
<tr>
<td>Robert M. Freund</td>
<td>24</td>
</tr>
<tr>
<td>Jeremie Gallien</td>
<td>24</td>
</tr>
<tr>
<td>Stephen C. Graves</td>
<td>25</td>
</tr>
<tr>
<td>Retsef Levi</td>
<td>25</td>
</tr>
<tr>
<td>James B. Orlin</td>
<td>25</td>
</tr>
<tr>
<td>Georgia Perakis</td>
<td>25</td>
</tr>
<tr>
<td>Andreas S. Schultz</td>
<td>26</td>
</tr>
</tbody>
</table>
OPTIMIZATION

OPERATIONS RESEARCH CENTER (ORC)

Codirectors: Cynthia Barnhart and Dimitris Bertsimas
http://www.mit.edu/~orc/

Operations Research is the discipline of applying advanced analytical methods to help make better decisions. Operations Research is characterized by its broad applicability and by a wide variety of career opportunities and work styles it embraces. It is also characterized by its interdisciplinary nature. The MIT ORC draws faculty from 8 different departments at MIT, including members from each school.

The Operations Research Center is the only interdepartmental center at MIT that both admits its own students and offers master's and doctoral degree programs. In both programs, students follow a core curriculum designed for education in fundamental OR methods and for early entry in research. Students are encouraged to select a set of courses that relates directly to their professional and research interests. The curriculum provides a strong background in the theoretical foundations of operations research and the practical techniques used in building models for a wide variety of applications.

The ORC enrolls 41 doctoral and nine master's degree students. Students represent a variety of academic backgrounds; approximately 50 percent from foreign countries; approximately one-third of the students are women. Students at the ORC have strong quantitative backgrounds and often rank at the top of their undergraduate classes.

Research activities at the Operations Research Center span a wide spectrum of methodological topics and applications, ranging from small, unsponsored projects involving a single faculty supervising a student's thesis to much larger, sponsored programs involving several faculty/staff and students.

Methodological research includes such topics as:
- mathematical programming and combinatorial optimization
- probabilistic combinatorial optimization
- solution methods for integer programming
- interior point methods for linear programming
- cluster analysis
- parallel and distributed computation and algorithms
- network flow algorithms
- network design
- deterministic and stochastic facility location
- queueing theory and queueing networks
- equitability in queueing systems
- risk analysis, stochastic processes
- classical and Bayesian statistics
- decision analysis and statistical decision theory
ORC faculty contribute to a wide range of application domains: flexible manufacturing systems; financial engineering services; marketing; transportation systems; life-cycle modeling of municipal solid waste; air traffic control; public services, such as urban emergency systems; criminal justice; safety and risk analysis in air transportation; communication systems; nuclear engineering; epidemiology; AIDS testing; supply chain management; industrial production and transportation logistics.

**COMPUTATION FOR DESIGN AND OPTIMIZATION (CDO) PROGRAM**

http://web.mit.edu/cdo-program/

The MIT CDO program was established in response to the emerging need to prepare tomorrow's engineers in advanced computational methods and applications. This interdisciplinary program provides a strong foundation in computational approaches to the design and operation of complex engineered and scientific systems. As of January 2009, 52 students have completed the CDO program. The CDO program educates students in the formulation, analysis, implementation, and application of computational approaches to designing and operating engineered systems, emphasizing:

- Breadth through introductory courses in numerical analysis and simulation, optimization, and applied probability
- Depth in optimization methods and numerical methods for partial differential equations
- Multidisciplinary aspects of computation
- Hands-on experience through projects, assignments, and a master's thesis

The research conducted by CDO’s affiliated faculty covers a wide range of topics in both methodology and applications. Methodological domains include:

- Complexity Theory
- Computational Mechanics
- Deterministic and Stochastic Facility Location
- Fast Solution Methods for Integral Equations
- Finite Element Methods
- Grid Generation
- Hybrid Atomistic-continuum Models
- Interior Point Methods for Convex Optimization
- Large Eddy Simulation
- Large-scale Optimization Solution Methods
- Linear Optimization (LP)
- Mathematical Programming and Combinatorial Optimization
- Molecular Modeling
- Monte Carlo Methods
- Multidisciplinary Design and Optimization
- Multiscale Material Modeling
- Numerical Linear Algebra
- Optimal Control of Distributed Systems
- Parallel and Distributed Computation and Algorithms
- PDE Optimization
- Probabilistic Combinatorial Optimization
- Real Time Computation
- Reduced Order Modeling/Reduced Basis Methods
- Robust Optimization
- Semidefinite Optimization (SDP)
- Solution Methods for Integer Programming
- Uncertainty Quantification for PDE-based Models
- Wavelets
Application domains include: Aeroacoustics; Aircraft Design; Air Traffic Control; BioMEMS; Cellular Manipulation; Communications Systems; Computational Aerodynamics; E-commerce; Fluid Structure Interaction; Internet; Inverse Problems; Large-scale Distributed Simulation; MEMS; Micro/Nanofluidics; Molecular Modeling; Molecular Separation and Manipulation; Nanoscale Fluid Mechanics; Revenue Management; Supply Chain Management

MIT CENTER FOR COMPUTATIONAL ENGINEERING (CCE)

Principal Investigator: Prof. Anthony T Patera
Other Investigator(s): Prof. Karen E Willcox
http://cce.mit.edu/

MIT's Center for Computational Engineering (CCE) was established in 2008. The broad mission of the CCE is to support computational engineering -- broadly defined as the development of methodologies that have strong demonstrated relevance to important engineering disciplines and problems. The center will have faculty and research partners from across the School of Engineering, as well as other departments and units involved in computational engineering around the Institute. The specific mission and strategic plan of the CCE are currently under development, but fully developed the center will play an active role both in both research- and education-related activities and objectives of the School of Engineering, and at MIT more broadly. CCE expects to engage and participate in the following activities:

(*) Presenting a unified face of computational engineering within MIT and to external constituencies
(*) Coordinating among MIT faculty who work in computational engineering to initiate and organize larger group efforts to raise research funds
(*) Investigating various possibilities for interdisciplinary PhD degree offerings in computational engineering
(*) Incorporating the existing Computation for Design and Optimization (CDO) master's program into CCE
(*) Facilitating and coordinating courses in computational engineering
(*) Participating in Institute-wide discussions on computational components of undergraduate education
(*) Awarding PhD fellowships in Computational Engineering
(*) Hosting a seminar series in Computational Engineering

COMPUTATIONAL ENGINEERING (CE)

Singapore-MIT Alliance (SMA)
Co-Chairs: Prof Khoo Boo Cheong (Singapore) and Prof. Jaime Peraire (MIT)
http://web.mit.edu/sma/research/ce/index.htm

Design-Simulate-Fabricate Micro-/Nano-fluidics for Cell and Biomolecule Manipulation, the CE Flagship Research Project (FRP), is focused on numerical design tools for biological applications of micromachining, also known as BioMEMS. We chose this application, in part, because effective BioMEMS design tools will enable an emerging industry that is certain to play a key role in biological research and biomedical devices. In addition, the BioMEMS design problem, which
couples mechanics, fluids, electrostatics, and non-continuum effects, serves the important pedagogical function of driving research in multidisciplinary simulation, optimization and methodology specialization.

Systematic investigation and understanding of biological systems depends on the tools available with which to probe their function. From micropipette to microarray, different interfaces with the biological world provide different functionalities. The vast majority of biological components—from small molecules to cells—exist in solution, and the ability to manipulate these components in microfluidic systems has already led to significant advances in experimental bioscience, from rapid DNA sequencing to micro-engineered tissues. A significant barrier to fully realizing these micro- and nano-fluidic systems is a limitation in our ability to model complex molecular and cellular phenomena within such devices, from the squeezing of DNA molecules through nano-sized channels to the mutual interactions of two cells in fluid flow. The goal of this FRP is to use radically improved modeling and optimization methodologies to streamline the design of microfluidic systems and the micro- and nano-elements within.

The objectives of this project are (i) to develop multidisciplinary simulation and optimization tools for designing micro-/nano-machined devices intended for biological or biomedical applications, and (ii) to use these tools to assist and enhance the design and fabrication process of micro- and nano-devices for manipulating biological cells and biomolecules. Specifically, we focus on the development of essential simulation and optimization tools, and design and fabrication, for three demonstration bio-fluidic devices:

- Nanofluidic biomolecule/bioparticle filters
- Electrostatic traps for massively parallel single-cell manipulation
- Mechanical filters for biomolecule and cell separation.

The above three devices are excellent drivers for simulation and modeling tool development, and they also represent important technology advances. In the near term, successful bio-molecule filters and cell-manipulation devices will make possible a wide variety of rapid in-vitro medical diagnostics. In the future, these devices could form the core of artificial tissues and/or organs.

In the process of developing and using simulation and optimization tools for designing these advanced micro- and nano-systems, we will expand the design tools available to developers of high-volume micro-systems for biomedical, chemical and sensor applications. The lack of such design tools has led to a longer-than-needed timeframe to market such micro-systems, and the high cost of mistakes has led to extremely conservative design practices. The new set of simulation and optimization tools could dramatically reduce this development cost, and therefore the risk, thus creating the opportunity for a much more aggressive expansion of the micro-systems industry.

For the simulation and optimization tools, we will develop methodologies to efficiently simulate a range of physical interaction among biomolecules, device structures and fluids, which are critical to manipulating cells and biomolecules in micro-/nano-fluidic systems. These methodologies will be realized as software for modeling multi-domain physics that is fast enough for use in design phase. We will use these methodologies to design and fabricate the three devices, each of which will take advantage of several of the methodologies. At the same time, experimental data from well-characterized micro- / nano-fluidic devices will be used to refine and verify the effectiveness of our methodologies.
AEROSPACE COMPUTATIONAL DESIGN LABORATORY (ACDL)

Principal Investigator: Prof. Jaime Peraire
http://acdl.mit.edu/

The Aerospace Computational Design Lab’s mission is to improve the design of aerospace systems through the advancement of computational methods and tools that incorporate multidisciplinary analysis and optimization, probabilistic and robust design techniques, and next-generation computational fluid dynamics. The laboratory studies a broad range of topics that focus on the design of aircraft and aircraft engines. There are 3 research thrusts:

(1) Advanced computational methods for fluid dynamics -- The goal is to improve the design process for complex 3D configurations by significantly reducing the time from geometry-to-solution at engineering-required accuracy using higher-order adaptive methods;
(2) Uncertainty quantification and control -- The goal is to improve the reliability of simulation-based analysis by quantifying and controlling sources of uncertainty in computational models; and
(3) Simulation-based design methodology.

The creation of computational decision-aiding tools in support of the design process is the objective of a number of methodologies currently pursued in the lab. These include PDE-constrained optimization, real-time simulation and optimization of systems governed by PDEs, multiscale optimization, model order reduction, geometry management, and fidelity management. ACDL is applying these methodologies to aircraft design and to the development of tools for assessing aviation environmental impact.

EVOLUTIONARY DESIGN AND OPTIMIZATION GROUP (EVO-DESIGNOPT)

Computer Science and Artificial Intelligence Laboratory (CSAIL)
Principal Investigator: Prof. Una May O’Reilly
http://groups.csail.mit.edu/EVO-DesignOpt/

FOCUS: Evolutionary Algorithms for optimization, machine learning and adaptive systems.

The unrelenting growth of complexity, data creation and tighter performance deadlines has given rise to problems that are unyielding to statistical or kernel-based machine learning techniques, convex optimization or evolutionary algorithms alone. However, a combination of these techniques can yield powerful algorithms and solutions.

EVO-DesignOpt explores efficient ways to combine different techniques to solve hard optimization and design problems in domains of high complexity. The techniques we develop can address problems related to:

• efficient exploitation of multicore processors
• parallel high-performance computing
• networks (communication, management)
• circuits (sizing, MOSFET modeling, IC-CAD)
• embedded systems (control, mapping)
• computer systems (compilers, run-time and operating scheduling and resource allocation)
• complex challenges such as transportation management, logistics, energy efficiency, and surveillance
• other domains with complex characteristics and specifications

Examples of evolutionary algorithms are:
Genetic Algorithms (GAs), Genetic Programming (GP), Evolutionary Strategies (ES), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Bayesian Optimization Algorithm (BOA).

HUMANS AND AUTOMATION LAB (HAL)

Director: Prof. Missy Cummings

Humans and Automation Lab (HAL) focuses on the multifaceted interactions of human and computer decision-making in complex sociotechnical systems. With the explosion of automated technology, the need for humans as supervisors of complex automatic control systems has replaced the need for humans in direct manual control. A consequence of complex, highly automated domains in which the human decision-maker is more on-the-loop than in-the-loop is that the level of required cognition has moved from that of well-rehearsed skill execution and rule following to higher, more abstract levels of knowledge synthesis, judgment, and reasoning.

Employing human-centered design principles to human supervisory control problems, and identifying ways in which humans and computers can leverage the strengths of the other to achieve superior decisions together is the central focus of HAL. Current research projects include collaborative human-computer decision making for command and control domains, investigating human understanding of multivariable optimization algorithms and visualization of cost (objective functions); the need for bounded collaboration, design of Lunar Lander displays, human supervisory control of multiple heterogeneous unmanned vehicles; collaborative time sensitive targeting; and developing metrics for evaluating display complexity.

AERONAUTICS AND ASTRONAUTICS

http://web.mit.edu/aeroastro/index.html

DAVID L. DARMOFAL
Professor of Aeronautics and Astronautics
Associate Head, Department of Aeronautics and Astronautics
http://raphael.mit.edu/darmofal.html
http://web.mit.edu/aeroastro/people/darmofal.html

Computational fluid dynamics, numerical analysis, probabilistic aerothermal design, and engineering education
OLIVIER L. DE WECK
Associate Professor of Aeronautics and Astronautics and Engineering Systems
Associate Director, Engineering Systems Division
http://esd.mit.edu/Faculty_Pages/deweck/deweck.htm
http://strategic.mit.edu/

Research interests:
Systems engineering for changeability and commonality
Space exploration logistics

Multidisciplinary Design Optimization
Multidisciplinary design optimization (MDO) focuses on optimizing the performance and reducing the costs of complex systems involving multiple interacting disciplines, such as those found in aircraft, spacecraft, automobiles, industrial manufacturing equipment, various consumer products, and on the development of related mathematical, computational and design methodologies.

MDO is a broad area that encompasses design synthesis, sensitivity analysis, approximation concepts, single and multi-objective optimization methods and strategies, rule-based design, and mathematical programming—all in the context of integrated design dealing with multiple disciplines and/or subsystem interactions.

Contributions to multidisciplinary design optimization include:
(*) Isoperformance - a method for obtaining sets of designs that meet a vector of performance targets within some numerical tolerance, while minimizing secondary objectives
(*) Adaptive Weighted Sum (AWS) multiobjective optimization
(*) Integrated System Level Optimization for Concurrent Engineering (ISLOCE) - including results from trials with human teams of designers
(*) Coupled vehicle design and network flow optimization for complex transportation systems
(*) Variable chromosome length genetic algorithm
(*) A modular state-vector based modeling and optimization approach. Application to Diesel exhaust after-treatment architectures

EMILIO FRAZZOLI
C.S. Draper Professor of Aeronautics and Astronautics
http://web.mit.edu/aeroastro/people/frazzoli.html
http://ares.lids.mit.edu/

Research interests:
Algorithmic, computational and geometric methods for design of complex control systems, in aerospace and other domains;
Applications in distributed cooperative control of multiple-vehicle systems, guidance and control of agile vehicles, mobile robotics, high-confidence embedded systems
JONATHAN P HOW
Professor of Aeronautics and Astronautics
Director, Aerospace Controls Laboratory (ACL)
http://web.mit.edu/aeroastro/people/how.html
http://www.mit.edu/~JHOW/

Specialization and Research Interests:
Navigation and Control: GPS sensing for navigation and control of formation flying vehicles, experimental and theoretical robust control, trajectory optimization and activity planning for multiple UAVs

Current research interests include the design and implementation of distributed real-time optimization algorithms to coordinate multiple autonomous vehicles in dynamic uncertain environments; and adaptive flight control to enable autonomous aerobatics. http://acl.mit.edu/

Flight Experiments Using Mixed-Integer Linear Programming (MILP) Trajectory Optimization
http://acl.mit.edu/projects/milp.html

Mixed-integer linear programming (MILP) provides a very general framework for capturing problems with both discrete decisions and continuous variables. Extensive research in the Aerospace Controls Lab (ACL) has explored ways of applying MILP to the control of unmanned aerial vehicles (UAVs). The standard MILP formulation has been used to model many UAV scenarios:

- Obstacle/collision avoidance and non-convex constraints
- Plume impingement
- Minimum-time trajectory problems
- Visibility graph-based cost-to-go models
- Multi-vehicle task assignment
- Hybrid systems
- Use of invariant sets for guaranteed safety

Recent work in MILP control has focused on the implementation of a three-dimensional trajectory optimization algorithm in the lab's indoor testbed, the Real-time indoor Autonomous Vehicle test Environment (RAVEN). This implementation is designed to fly quadrotor UAVs in a three-dimensional obstacle environment. The MILP formulation uses non-uniform timesteps to design a detailed plan for the short term and a coarse plan for the long term. Additional upgrades include an expanding reachable horizon, such that only nearby obstacles are included in the formulation, and linear interpolation points to reduce the "discretization gap" between timesteps.

AMEDEO R. ODONI
Professor at the Department of Aeronautics and Astronautics
http://web.mit.edu/aeroastro/people/odoni.html

Research interests:
Optimization algorithms for air traffic control flow management
Uncertainty in advanced traffic management system
Model to compute delays on network of airports
Computer-aided design of airport passenger terminals
Approximate dynamic queuing models with airport applications
Risk assessment for railroads
Probabilistic extensions and variations of classical combinatorial optimization models

JAIME PERAIRE
Professor of Aeronautics & Astronautics
Director, Aerospace Computational Design Laboratory
Co-Director, Program in Computation for Design and Optimization
http://web.mit.edu/aeroastro/people/peraire.html
http://raphael.mit.edu/PERAIRE.bio.html

Research Interests:
Numerical Analysis, Finite Element Methods, Computational Aerodynamics

RAUL RADOVITZKY
Charles Stark Draper Associate Professor of Aeronautics and Astronautics
http://web.mit.edu/aeroastro/people/radovitzky.html
http://web.mit.edu/aeroastro/people/radovitzky/

Research interests:
Computational solid mechanics and fluid
Structure interaction
Mechanics of materials
Multiscale modeling and simulation
High-performance and massively parallel computing

KAREN E. WILLCOX
Associate Professor of Aeronautics and Astronautics
http://raphael.mit.edu/willcox.html
http://web.mit.edu/aeroastro/people/willcox.html

Research interests:
Reduced-order modeling
Multidisciplinary design optimization
Environmental issues in aircraft design
Aircraft system design for value
Design space visualization
Blended-wing-body

BRIAN C. WILLIAMS
Professor of Aeronautics and Astronautics
http://web.mit.edu/aeroastro/people/williams.html
Research interests:
Space and aerial robotics, cognitive robotics, automated reasoning and artificial intelligence, automation for operations and design, hybrid control systems

CHEMICAL ENGINEERING

http://web.mit.edu/cheme/

PAUL I. BARTON
Lammot du Pont Professor of Chemical Engineering
http://web.mit.edu/cheme/people/profile.html?id=2
http://yoric.mit.edu/

Research interests:
Dynamic modeling, simulation and optimization
Hybrid and embedded systems
Mixed-integer and global optimization theory and algorithms
Design and operation of micro-scale chemical processes;
Systems biology
Energy systems engineering

WILLIAM H. GREEN
Professor of Chemical Engineering
http://web.mit.edu/cheme/people/profile.html?id=13
http://web.mit.edu/greengp/

Research interests:
Chemical kinetics
Molecular simulation
Free radical reactions

CIVIL AND ENVIRONMENTAL ENGINEERING

http://cee.mit.edu/

CYNTHIA BARNHART
Associate Dean of Engineering for Academic Affairs and Professor of Civil and Environmental Engineering
http://engineering.mit.edu/about/deans_office/cynthia_barnhart.php

Research interests:
Development and application of linear, integer and network optimization models and methods to large-scale transportation systems
MARKUS J. BUEHLER
Esther and Harold E. Edgerton Assistant Professor of Civil and Environmental Engineering
http://cee.mit.edu/buehler
http://web.mit.edu/mbuehler/www/

Research interests:
Materials science and mechanics of natural and biological protein materials - how proteins define our body and how they fail catastrophically (fracture, deformation)
Large-scale atomistic modeling
Protein based materials and biopolymers
Interaction of chemistry and mechanics
Bridging chemical scales to continuum theories of materials
Modeling of bio-nano-materials phenomena
Multiple-scale simulation
Development of multi-scale simulation tools

PATRICK JAILLET
Edmund K. Turner Professor of Civil and Environmental Engineering
Department Head, Civil and Environmental Engineering
http://cee.mit.edu/jaillet
http://web.mit.edu/jaillet/www/

Research interests:
On-line problems; real-time and dynamic optimization; network design and optimization; probabilistic combinatorial optimization; financial engineering

DAVID SIMCHI-LEVI
Professor of Civil and Environmental Engineering
http://cee.mit.edu/simchi-levi
http://slevi1.mit.edu/

Research Interests:
Transportation and logistics systems analysis
E-Commerce and supply chain management
Revenue and yield management
Optimization based decision support systems
Operations research
Telecommunications systems
ECONOMICS

http://econ-www.mit.edu/

IVAN WERNING
Professor of Economics
http://econ-www.mit.edu/faculty/iwerning
http://econ-www.mit.edu/faculty/iwerning/papers

Research interests:
Macroeconomics
Public economics
Applications of dynamic contracts
Optimal taxation
Monetary policy
Unemployment insurance design

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

http://www.eecs.mit.edu/

DIMITRI P. BERTSEKAS
McAfee Professor of Electrical Engineering
http://mit.edu/dimitrib/www/home.html

Research interests:
Linear and nonlinear programming
Network optimization
Dynamic and neuro-dynamic programming
Estimation and control of stochastic systems
Neural networks
Parallel and distributed computation
Data communication networks

MUNTHE A. DALEH
Professor of Electrical Engineering
http://web.mit.edu/dahleh/www/index.htm

Research Interests
Optimal and Robust control synthesis with logic and discrete constraints
Model Reduction of Stochastic Hybrid Systems
The interplay between Information and Decision-making
Distributed control of Networked Systems
Learning in Games and Application to learning in complex social networks
Neurobiology with focus on cerebellar control and understanding cortical oscillations
Automotive Applications

**LUCA DANIEL**
Emanuel E. Landsman Career Development Associate Professor of Electrical Engineering
http://www.mit.edu/~dluca/
http://www.rle.mit.edu/rleonline/People/LucaDaniel.html
http://www.rle.mit.edu/cpg/

Research interests:
Parameterized model order reduction of linear and nonlinear dynamical systems
Mixed-signal, RF and mm-wave circuit design and robust optimization
Power electronics, MEMs design and fabrication
Parasitic extraction and accelerated integral equation solvers

**PETER L. HAGELSTEIN**
Associate Professor of Electrical Engineering
http://www.rle.mit.edu/rleonline/People/PeterL_Hagelstein.html

Research interests:
Thermal to electric conversion
Thermal diodes
Transport modeling
Metal deuterides
Quantum excitation
Low energy nuclear physics
Cold fusion

**THOMAS L. MAGNANTI**
Institute Professor
http://www.csail.mit.edu/user/1327

Research interests:
Optimization theory
Production planning and scheduling
Transportation planning
Facility location
Logistics
Communication systems design

**Network Design and Optimization**
08/08/08
This project would develop optimization approaches (models and solution procedures) for large-scale complex network systems that arise in transportation or telecommunications settings. It would focus on problems that are combinatorially complex such as those that occur in vehicle
routing and scheduling, or in the design of cost efficient and reliable telecommunications systems, such as the internet. The project would focus on generic models and solution approaches that could be applied in many specific application settings. The research would build upon collaboration of several years by the two co-PI that have addressed issues in these general problem domains.

ALEXANDRE MEGRETSKI
Professor of Electrical Engineering and Computer Science
http://web.mit.edu/ameg/www/

Research interests:
Nonlinear dynamical system analysis
Design and validation of hybrid control algorithms
Optimization (LP, LMI, convex, non-convex, etc.)
Applications: flight control, control of production, control of animated objects, relay systems

SANJOY K. MITTER
Professor of Electrical Engineering
http://web.mit.edu/~mitter/www/

Research interests:
Theory of stochastic and adaptive control
Mathematical physics and its relationship to system theory
Image analysis and computer vision
Structure, function and organization of complex systems

UNA MAY O’REILLY
Principal Research Scientist, Computer Science and Artificial Intelligence Laboratory (CSAIL)
http://people.csail.mit.edu/unamay/
http://www.csail.mit.edu/user/824

Research: Solutions for complex systems: from traffic to a desktop computer's activity, every system is becoming more complex. There's more data, less time and more things that interact. The problems are harder, bigger and more intertwined. Since nature solved this problem, I am considering how bio-inspired algorithms (on their own or in tandem with other techniques) can be practically deployed to accommodate the demands of dynamic adaptation or optimization. Current projects consider these challenges in the context of networks (for communication or biosynthesis via metabolic network knockouts), multi-core computer architectures and analog circuit CAD.

ASUMAN E. OZDAGLAR
Class of 1943 Career Development Associate Professor of Electrical Engineering
http://web.mit.edu/asuman/www/

Research Interests:
Nonlinear optimization and convex analysis
Game theory
Network economics; pricing and resource allocation games
Distributed optimization methods
Network optimization and control; wireless and wireline networks

PABLO A. PARRILO
Finmeccanica Career Development Professor of Engineering
http://www.mit.edu/~parrilo/

Research interests:
Optimization methods for engineering applications
Control and identification of uncertain complex systems
Robustness analysis and synthesis
Development and application of computational tools based on convex optimization and algorithmic algebra to practically relevant engineering problems

DEVAVRAT SHAH
Jamieson Career Development Assistant Professor. Electrical Engineering & Computer science
http://web.mit.edu/devavrat/www/

Research interests:
Network algorithms
Stochastic networks
Network information theory and large scale statistical inference

VLADIMIR STOJANOVIC
Assistant Professor of Electrical Engineering
http://www.rle.mit.edu/isg/people_stojanovic.htm
http://www.rle.mit.edu/isg/

Professor Stojanovic's research interests include optimization of integrated circuits and systems application of convex optimization to digital communications, analog and VLSI circuits, modeling of noise and dynamics in circuits and systems, communications and signal processing architectures, high-speed electrical and optical links, on-chip signaling, clock generation and distribution and high-speed digital and mixed-signal IC design.

JOHN N. TSITSIKLIS
Clarence J. Label Professor of Electrical Engineering and Computer Science
http://mit.edu/jnt/www/home.html

Research interests:
Communication networks (resource allocation, games, queuing)
Neuro-Dynamic Programming (large-scale dynamic programming and reinforcement learning)
Analysis and control of stochastic systems
Computational complexity in systems and control
Dijkstra-like methods for the eikonal equation ("fast marching")
Flocking and consensus
Parallel and distributed computation
Data fusion (communication complexity and decentralized detection)
Optimization, control, and system identification
Estimation and learning

GEORGE C. VERGHESE
Professor, Education Officer, Department of Electrical Engineering and Computer Science
http://eeecsfacweb.mit.edu/facpages/verghese.html
http://lees.mit.edu/lees/verghese_g.htm

Research interests:
Structure and dynamics of networked systems; estimation, control, signal processing; physically-based model reduction; applications, especially in biomedicine, biology and power systems

JACOB K. WHITE
Cecil H. Green Professor at the Department of Electrical Engineering and Computer Science
http://www.rle.mit.edu/rleonline/People/JacobK.White_cv.html
http://www.rle.mit.edu/cpg/

Research interests:
Simulation and optimization
Computational prototyping
Numerical techniques
Integral equations
Integrated circuit interconnects
Micromachined devices
Biomolecules
Sensors and actuators

MATERIALS SCIENCE AND ENGINEERING
http://www.eecs.mit.edu/

JOEL P. CLARK
Professor of Materials Systems
http://dmse.mit.edu/faculty/faculty/jpclark/

Research interests:
Analysis of relationship between technology and economics in materials industries
Establish comprehensive and consistent framework for analyzing markets for minerals over next 10-20 years, and costs of supplying markets
Apply framework to study of dynamic behavior of supply, demand, and prices in specific materials markets

**MATHEMATICS**

http://math.mit.edu/index.php

**ALAN EDELMAN**
Professor of Applied Mathematics
http://www-math.mit.edu/~edelman/
http://math.mit.edu/people/profile.php?pid=63

Research interests:
Support vector machines
Random matrices
Applying linear algebra to MRI

**MICHEL X. GOEMANS**
Leighton Family Professor of Applied Mathematics
Chairman, Committee on Applied Mathematics
http://math.mit.edu/people/profile.php?pid=84
http://math.mit.edu/~goemans/

Research interests:
Theoretical Computer Science, Combinatorial Optimization

**BENJAMIN SEIBOLD**
Instructor of Applied Mathematics
http://www-math.mit.edu/~seibold/
http://math.mit.edu/people/profile.php?pid=240

Research interests:
Meshfree methods for partial differential equations
Particle methods
Level set methods
Traffic flow (nonlinear detonation waves in macroscopic models)
Underresolved computation and averaged truncation
Radiative transfer
Computational fluid dynamics
PETER W. SHOR
Morss Professor of Applied Mathematics
http://math.mit.edu/~shor/

Research interests:
Algorithms
Quantum computing
Computational geometry
Combinatorics

MECHANICAL ENGINEERING

http://meche.mit.edu/

ROHAN ABEYARATNE
Quentin Berg Professor of Mechanics
http://meche.mit.edu/people/faculty/index.html?id=1

Research interests:
Continuum mechanics
Finite elasticity and plasticity
Material instability and non-equilibrium behavior of solids
Stress induced phase transformations in solids
Cavitation

DANIEL D. FREY
Robert Noyce Career Development Associate Professor of Mechanical Engineering and Engineering Systems
http://meche.mit.edu/people/faculty/index.html?id=27

Research interests:
Robust design of engineering systems

DAVID C. GOSSARD
Professor of Mechanical Engineering
http://meche.mit.edu/people/faculty/index.html?id=31

Research interests:
Computer-aided design
Computational geometry
Numerical optimization (Mathematical Programming) is a tremendously useful tool for engineers. We extensively use optimization algorithms for solving engineering problems. Robust and reliable algorithms and commercial software packages exist for many formulations. However, significant algorithmic development is still required in other cases, in particular embedded programs (bilevel and SIP) under nonconvexity.
NICHOLAS M. PATRIKALAKIS
Kawasaki Professor of Engineering
Professor of Mechanical and Ocean Engineering
http://meche.mit.edu/people/faculty/index.html?id=67

Research interests:
Computer-aided design
Computational geometry
Visualization
Dynamic data-driven forecasting systems

JAMES C. PREISIG
Associate Scientist
Applied Ocean Physics & Engineering
http://www.whoi.edu/dept/profile.go?id=335

Research interests:
Acoustic propagation modeling
Signal processing
Numerical optimization
Communications

SANJAY E. SARMA
Associate Professor of Mechanical Engineering
Former Chairman of Research and Co-Founder of The Auto-ID Center at MIT
http://meche.mit.edu/people/faculty/index.html?id=74

Research interests:
Computer aided design
Solid modeling
Computational geometry
Computer aided manufacturing
Machine tool automation
Machine tool design
Automatic identification
Radio frequency identification
Integrated circuit packaging
Enterprise software
Supply chain management
SLOAN SCHOOL OF MANAGEMENT

http://mitsloan.mit.edu/

DIMITRIS J. BERTSIMAS
Boeing Professor of Operations Research
Operations Research/Statistics
http://mitsloan.mit.edu/faculty/detail.php?in_spseqno=10&co_list=F
http://www.mit.edu/~dbertsim/

Research interests:
Air-traffic control; e-commerce; financial engineering; operations research (data mining); optimization; revenue management; statistics (stochastic modeling)

VIVEK F. FARIAS
Assistant Professor
Operations Management/System Dynamics
http://mitsloan.mit.edu/faculty/detail.php?in_spseqno=28714&co_list=F
http://web.mit.edu/vivekf/www/

Research interests: Revenue management; Dynamic optimization; Analysis of complex stochastic systems

ROBERT M. FREUND
Deputy Dean, Theresa Seley Professor of Management Science
http://mitsloan.mit.edu/faculty/detail.php?in_spseqno=43&co_list=F
http://web.mit.edu/rfreund/www/

Research interests:
Applied math; education (b-school, business education, distance learning, MBA, research-academic); operations research (decision making decision support, mathematical programming); optimization

JEREMIE GALLIEN
J. Spencer Standish (1945) Associate Professor of Operations Management
http://mitsloan.mit.edu/faculty/detail.php?in_spseqno=17383&co_list=F
http://web.mit.edu/jgallien/www/

Research interests:
Applied mathematics; e-commerce; Europe; France; Internet auctions; operations management (inventory, logistics, supply chain management); operations research (decision making-decision support); optimization; pricing; retailing; revenue management; sales automation; sales support
systems and databases; simulation; Singapore; statistics (applied probability, stochastic modeling)

**STEPHEN C. GRAVES**  
Abraham J. Siegel Professor of Management Science  
Professor of Mechanical Engineering and Engineering Systems  
http://web.mit.edu/sgraves/www/  
http://mitsloan.mit.edu/faculty/detail.php?in_spseqno=49&co_list=F  

Research interests:  
Supply chain optimization  
Strategic inventory positioning in a supply chain  
Tactical issues in e-retailing  
Production planning and scheduling for various contexts

**RETSEF LEVI**  
Associate Professor of Finance  
Operations Management/System Dynamics  
http://mitsloan.mit.edu/faculty/detail.php?in_spseqno=27458&co_list=F  
http://web.mit.edu/retsef/www/  

Research interests:  
Design of efficient algorithms for stochastic optimization  
Combinatorial optimization and mathematical programming  
Approximate dynamic programming  
Data-driven algorithms  
Applications to supply chains, revenue management, and logistics

**JAMES B. ORLIN**  
The Edward Pennell Brooks Professor of Operations Research  
Operations Research/Statistics  

Research interests:  
Advertising; airlines; optimization; operations research (decision-making, decision support, mathematical programming); transportation

**GEORGIA PERAKIS**  
J. Spencer Standish Career Development Professor  
Operations Research/Statistics  
http://web.mit.edu/~georgiap/www/  

Research interests:
Airlines; auctions; competition; e-commerce; inventory; operations research; optimization; pricing; revenue management; transportation

**ANDREAS S. SCHULTZ**
Professor of Operations Research
Operations Research/Statistics
http://web.mit.edu/schulz/

Research interests:
Combinatorial Optimization, Integer Programming, Algorithmic Game Theory