Laboratory for Information and Decision Systems

The Laboratory for Information and Decision Systems (LIDS) is an interdepartmental laboratory for research and education in systems, control, optimization, communication, networks, and statistical signal processing. These disciplines, which span the domain of the analytical information and decision sciences, play a critical and pervasive role in science, engineering, and society more broadly. At its best, LIDS provides a melting pot of disciplines that share a common approach to problems, a common mathematical base, and an energized environment not only to foster the research needed for the future but also to instill in our students the disciplinary depth and the interdisciplinary understanding required of research and engineering leaders of today and tomorrow.

LIDS draws its staff principally from the Department of Electrical Engineering and Computer Science as well as from the Department of Aeronautics and Astronautics. However, because the disciplines in which LIDS is involved are also of great interest across the Institute, we maintain—and are in the process of growing—our collaborations and interactions with many other units, including the Operations Research Center; the Computer Science and Artificial Intelligence Laboratory; the Research Laboratory for Electronics; the MIT Energy Initiative; the Departments of Civil and Environmental Engineering, Mechanical Engineering, Earth and Planetary Sciences, Brain and Cognitive Science, and Economics; the Sloan School of Management; and the Harvard–MIT Division of Health Sciences and Technology. In addition, LIDS has a strong and growing set of interactions with industrial organizations, which provide funding, collaborators, and challenging problems to drive our research. Among the organizations with which we have or are developing interactions are Draper Laboratory, Lincoln Laboratory, Los Alamos National Laboratory, Siemens Corporation, Shell Oil Corporation, Ford Motor Company, and Boeing. Also, thanks to a rich history of research excellence and leadership, LIDS remains a magnet for the very best, attracting not only outstanding students and faculty but also a continuing stream of world-leading researchers as visitors and collaborators.

LIDS Intellectual Vision and Research Areas

The domain of research in LIDS can be described along several different dimensions:

- A common set of mathematical disciplines, including probability and statistics, dynamical systems, and optimization and decision theory
- A set of core engineering disciplines—namely, inference and statistical data processing, transmission of information, networks, and systems and control
- A set of broad challenges, emerging applications and critical national or international needs, and intellectual opportunities

Research at LIDS involves activities within and across all these dimensions. The convergence of issues that arise in the challenges of the present and future has led us to research that cuts across mathematical and engineering disciplines in new, exciting, and important ways. Research flows in both directions across these dimensions: work in each of the mathematical disciplines leads to new methodologies that enable advances in core disciplines and in interdisciplinary investigations; work in attacking those emerging interdisciplinary challenges provides direction and drivers for fundamental disciplinary activities and has led to the charting out of emerging new disciplines.

In particular, the availability of increasingly capable sensing, communication, and computation systems enables the collection and transfer of large amounts of data pertaining to complex and heterogeneous interconnected systems. The need for an intellectual platform to simultaneously address questions of data fusion, distributed learning, information transfer, and distributed decision making is stronger than ever as existing techniques fall short in addressing issues of scalability, robustness, and performance limits. Examples of areas in which LIDS research has and will continue to contribute include the following:

- Intelligence, surveillance, and reconnaissance systems
- Coordination of unmanned autonomous systems
- Energy information systems
- Biological systems and biomedical data analysis
- Large-scale data assimilation for the geosciences
- Network scheduling and routing
- Sensor networks
- Social network analysis and characterization
- Ultra-wideband and other emerging communications technologies.

Furthermore, traditional paradigms of sensing, communication, and control are not adequate to address many of the emerging challenges that we see before us. As a result, we have initiated a set of fundamental research themes that cut across disciplinary boundaries and involve considerable interaction and collaboration with colleagues in other units at MIT and in other disciplines:

- Foundations of network science, including network algorithms, approximation, and information
- Foundations of decision theory for teams involving cooperation and competition including dynamic mechanism design in game theory, learning in stochastic games, and the study of rational decisions for large interacting networks of agents
- Foundations of cyber-physical systems, including architectural design, cross-layer algorithms, and tools for analysis, verification, and performance guarantees
- Foundational theory for multiscale/granularity modeling, including methods for describing complex phenomena at multiple granularities, learning of such models from complex and heterogeneous data, and reduction/simplification of models to levels appropriate for particular questions of analysis or design

Activities of LIDS Faculty

In this section, we summarize the major research activities of the faculty in LIDS, noting first that much of this research not only cuts across the disciplines, applications, and emerging areas mentioned previously but also is collaborative with others within LIDS and elsewhere at MIT.

Professor Dimitri Bertsekas

Professor Dimitri Bertsekass interests are in analytical and computational aspects of optimization and large-scale computation, and their applications, particularly in optimal control and data communication networks. Within these contexts, he has authored several books and research monographs on dynamic programming and stochastic control, nonlinear programming, network optimization, convex optimization, parallel and distributed computation, and data network theory.

One of his main present interests is in deterministic optimization problems and the role of convexity in solving them, possibly through the use of duality. He is writing a book on the subject that involves new research on the fundamental structures that guarantee the existence of optimal solutions while eliminating duality gaps. Recent effort has focused on separable large-scale convex optimization problems, known as monotropic programming problems, for which special duality results and algorithms are possible.

Another of his main present interests lies in problems of sequential decision making under uncertainty, which are pervasive in communication networks, manufacturing systems, and logistics and in the control of nonlinear dynamical systems. In theory, such problems can be addressed with dynamic programming techniques. In practice, only problems with a moderately sized state space can be handled. This research effort deals with the application of neural networks and other approximation and interpolation methodologies to overcome the curse of dimensionality of real-world stochastic control problems. Recent effort has focused on the use and analysis of popular temporal difference methods in the context of fully and partially observable Markov decision problems. In particular, an investigation of a broad extension of these methods has been developed to solve large linear systems of huge dimension by using projections on lower dimensional subspaces of basis functions.

Professor Robert Berwick

We initiated major new research efforts in two areas:

- Biolinguistics, combining results from evolutionary biology, computation and dynamical systems, and language change
- Statistical learning theory and parsing, initiating the first systematic analysis of the strengths and weaknesses of statistical parsing systems, trained on large databases, including the development of publicly available visualization tools

Both research efforts led to major MIT conferences, two new MIT Press books, and conference publications. Highlights follow.

We organized a major international workshop on language and statistics, held October 14, 2007, "How is syntax learned? Have we all been wrong?" that brought together for the first time dozens of scientists from three generally disparate communities—linguistics, cognitive science, and computer science—speaking to an audience of 1,500. The results of the workshop will be forthcoming as an MIT Press book.

We launched a new program in biolinguistics, including a review paper approved to appear in *Science* early next year, with a companion review paper to appear in *Current Biology*; National Science Foundation (NSF) funding for a major workshop in biolinguistics with James Watson, Jean-Pierre Changeux, and Sean Carroll on the biological side; several major new papers published on the biology of language and evolution.

We obtained several new scientific results in the area of biolinguistics, including new results on bird song and language: externalization based on metrical structure of language, similar in origin. (Portions of this work were highlighted on a PBS television show.) Specifically, we implemented a parser for metrical or rhythmic structure of sound patterns as well as a learning system based on professor Morris Halle's theory of metrical stress. It has been applied to the sound patterns of human speech and bird song, with the aim of uncovering the similar substrate underlying human and avian vocalization.

We completed the manuscripts for two books to be published by MIT Press, one on a multiple-language parser and the second on our year-long analysis of the strengths and limits of statistical language parsing. This research was made possible by LIDS' hosting of professor Sandiway Fong from the University of Arizona at Tuscon during the spring semester at LIDS, in part with the generous support of professor Sanjoy Mitter.

- *Pappi: A Linguistically-grounded Parsing System*, MIT Press, Cambridge, MA
- *Against All Odds*, MIT Press, Cambridge, MA

We completed research in the following other areas, followed by capstone papers that appeared in the major conferences in these areas, and archival journals:

- Language change and dynamical systems, including a new estimation technique for the parameters of language change, with two papers to appear, one in the *Proceedings of the National Academy of Sciences*, and a longer version in the journal *Cognitive Science*, "The proper treatment of language acquisition and change in a population setting."
- Human language and evolutionary biology. Two major research topics were completed. First, with Noam Chomsky we coauthored a paper reviewing the current biological basis for understanding the constraints on language "design," including our current knowledge of the genomic analysis of language, concluding that the constraints on language are derived largely from "internal" constraints with the conceptual/semantic system. Second, we developed new mathematical models for simulating the possible evolution of language, given new evidence that adaptation proceeds by larger "jumps."
- Language, learning theory, and statistical analysis. We carried out the first extensive cross-validation studies of statistical language parsers, uncovering

inherent weaknesses given the sparsity of the data behind such systems. Along with new software visualization tools described below, this study led us to develop "cognitive Turing tests" for such parsers as well as a way to significantly improve the reliability of such systems. We completed a system that can learn quantifiers such as "each," "a," and "every" by exposure to simple positive examples, using Bayesian methods, the first known system of its kind.

Finally, we developed a novel algorithm for comparing linguistic/parser trees, called linguistic edit distance (LED). Previous work in this area employed a simple "parenthesis matching" method. Partly for this reason, results in this area have stagnated because the objective function metric does not say how to improve results. Further, standard algorithmic methods for tree matching based on insert, delete, and rename operations are not linguistically natural. We need to define operations that are supported by all linguistic theories—hence LED, which is based on operations that correspond to independently justified primitives of linguistic (and psycholinguistic) theory, such as displacement of entire subtrees. LED turns out to be a better metric for evaluating linguistically "relevant" distance between a known parse structure and a trained parse structure. It leads immediately to an improved objective function for parsing and improved results. We developed several new, publicly available software visualization tools for examining large training sets in this area, as well as parse tree output.

Professor Munther Dahleh

Professor Munther Dahleh has led a research effort focused on control of networked systems, with emphasis on the problem of distributed decision making and control under limited observations and communications. This work includes problems of coordination of mobile agents, control in the presence of communication constraints, and distributed computation over networked computational units.

Limitations of Networks on Control and Optimization

With his students Nuno Martins and Sridevi Sarma, he analyzed the effect of noisy channels in standard feedback and feed-forward networks on the achievable performance measured in terms of tracking and disturbance attenuation. These results provided a bridge between information theory (capturing the limitations on maximum transmission rate) and control theory (capturing the limitation of noise cancellation). Professors Dahleh and Devavrat Shah and their student Ola Ayaso collaborated on understanding the effect of finite-capacity multiagent networks on distributed function computation. In this context as well, information theory is linked to distributed computation and optimization of special classes of functions.

Fundamental Limitation of Performance in Mobile Networks

In collaboration with Professor Shah and student Holly Waisanen-Hatipoglu, Professor Dahleh used scaling results to derive polynomial time algorithms that achieve near-optimal performance (in terms of average delay) for a class of vehicle routing problems with network constraints. In collaboration with professor Emilio Frazzoli and their student Sleiman Itani, they showed how to incorporate kinematics and dynamic constraints into such vehicle routing problems and still achieve near-optimal performance. This work drew from various areas including control and information theory, stochastic processes and queuing theory, and geometric optimization techniques.

Learning in Large Social Networks

In collaboration with professors Asuman Ozdaglar and Daron Acemoglu, Professor Dahleh and his student Ilan Lobel led an effort in understanding sequential learning problems that arise in social networks. Their work focused on analyzing Bayesian learning for sequential decision makers who base their decision on observing a subset of the previous decision makers and external signals sampled from a distribution conditioned on the correct state of the world. Their work provided necessary and sufficient conditions on the observations and external signals that guarantee asymptotic learning of a binary state of the world. They also provided results on the speed of convergence for specific classes of learning problems.

Automotive Application

Along with his students Michael Rinehart and Yola Katsargyri, Professor Dahleh led a collaboration with Ford focusing on the utilization of GPS information to minimize fuel consumption in a hybrid car by optimally switching between the electric motor and the engine. The work relies on using road information such as road slope, traffic lights, and other road attributes to plan trajectories as well as engine-switching strategies that will produce optimal fuel consumption. The methods produced favorable results on the Ford simulator of a hybrid car.

Professor Emilio Frazzoli

Professor Emilio Frazzoli's main research interests are in the area of control of autonomous vehicles, and of mobile robotic networks, with emphasis on symbolic and algorithmic methods.

Probably the most visible outcome of Professor Frazzoli's work in the past year has been MIT's entry to the 2007 Defense Advanced Research Projects Agency (DARPA) Urban Challenge (DUC). The DUC was a competition for autonomous street-legal ground vehicles, required to drive through a representative urban environment, accomplishing a number of missions for a total of about 60 miles. The vehicles were required to interact safely with traffic, including robotic and human-driven vehicles, and abide by the rules of the road, demonstrating capabilities on par with the requirements for a California driver's license. MIT's vehicle, an instrumented Land Rover called Talos, was one of only six vehicles among the 89 participants that were able to finish the race, demonstrating an unprecedented level of capability, safety, and reliability. In particular, MIT placed fourth according to DARPA's official timing and was the highest-ranking first-time entry in the competition. Professor Frazzoli, in collaboration with professor Jonathan How and their respective students (including Sertac Karaman, a graduate student in LIDS), was responsible for developing the planning and control system.

The other main focus of Professor Frazzoli's research is on developing analysis and synthesis tools for control of mobile robotic networks. Within the context of several NSF-sponsored projects on the topic, his research group is analyzing a broad class of multiple-vehicle motion coordination problems, from dynamic vehicle routing to path coverage and traffic deconfliction. Recent advances include the analysis of dynamic vehicle routing problems with priority demands and customer impatience and the discovery of an endogenous phase transition in the optimal network "social" organization caused by the vehicles' dynamics. Such phase transitions have been observed in biological systems, but the understanding of such phenomena is still very limited.

As part of a new multiyear collaborative effort on control science with the Air Force Research Laboratory and the University of Michigan, Professor Frazzoli is investigating mission planning and control systems for heterogeneous, mixed-initiative networks of unmanned aerial vehicles (UAVs), piloted aircraft, and human operators. During the past year, a new computational framework has been proposed, enabling the computation of optimal mission plans subject to complex logic and temporal constraints. Also, Professor Frazzoli and his students are developing strategies for UAV mission planning that embed cognitive models of human operators, explicitly taking into account the effects of human operators, workload, and situational awareness.

Other projects address diverse topics such as high-speed off-road driving (with Karl Iagnemma), agile robotics for Army logistics (with Seth Teller, Jonathan How, and several others), and autonomous and reconfigurable cyber-physical systems (with Munther Dahleh, Pablo Parrilo, and others).

Professor Alexandre Megretski

Professor Alexandre Megretski's main area of current research interest is optimization-based tools for identification and identification-based model reduction of nonlinear systems. Essentially, this is a "data mining" setup, in which a simple, stable dynamical relation is to be extracted from raw data. A recent joint initiative with professors Vladimir Stojanovic, Luca Daniel, and Joel Dawson aims to achieve a breakthrough in dynamical modeling of parameter-dependent circuits by extracting simple nonlinear parameter-dependent dynamical models from simulation and physical measurements.

Another effort aims to develop a comprehensive theoretical framework for modeling, analyzing, and synthesizing systems that can be approximated well by finite state automata. This direction relies on progress made in optimization-based analysis of nonlinear dynamical systems, model reduction of finite state automata, and an impact map theory for hybrid systems.

Professor Megretski also leads a research effort investigating benefits of applying tools of robust control to real-time software analysis, with a specific focus on run-time errors. He takes part in joint research with professor Russ Tedrake on modeling, identification, analysis, and utilization of real neural networks as well as in a project with professor Jovan Popovic on the use of nonlinear control theory in computer animation.

Professor Sanjoy Mitter

Professor Sanjoy Mitter's research has spanned the broad areas of systems, communication, and control. Although his primary contributions have been on the theoretical foundations of the field, he has also contributed to significant engineering applications, notably in the control of interconnected power systems and pattern recognition. His current research interests are theory of stochastic and adaptive control; mathematical physics and its relationship to system theory; image analysis and computer vision; and structure, function, and organization of complex systems.

Professor Mitter has continued his long-standing collaboration with Dr. Charles Rockland (RIKEN Brain Science Institute, Tokyo, Japan) on issues of autonomy and adaptiveness in neural systems. There is renewed interest in studying the nematode from the viewpoint of understanding the structure-to-function map—a program they proposed in the 1980s.

In joint work with Emery Brown (Department of Brain and Cognitive Sciences, MIT) and former doctoral student L. Srinivasan, Professor Mitter has been investigating the role of point process theory in representing the spiking response of premotor dorsal cortex (PMd). A quantitative theory of the role of PMd in movement control requires that the whole delay period spiking response of PMd be understood as well as specific features that describe it in part. An adequate mathematical model of PMd must capture the effects of a physical system governed by local neuronal properties and anatomical connections with numerous cortical and subcortical areas.

In addition, Professor Mitter has continued his collaboration with Dr. Nigel Newton (University of Essex, UK) on the relation between statistical mechanics, statistical inference, and information theory. In recent work, they have given a proof of the noisy channel coding theorem (including error exponents) from the variational point of view of Bayesian inference.

Investigations on the subject of the interaction of information and control have continued with Anant Sahai (University of California, Berkeley) and Sekhar Tatikonda (Yale University).

Also with Anant Sahai, Professor Mitter has shown for the first time that unstable processes generate two fundamentally different kinds of information, one requiring Shannon capacity for its reliable transmission and one requiring anytime capacity for its reliable transmission. Completion of this work required developing new rate distortion theory for a family of channels. This work constitutes part of Mukul Agarwal's doctoral thesis. With doctoral student, Lav Varshney, he is studying the problem of reliably transmitting both energy and information over a noisy channel.

Professor Asuman Ozdaglar

Professor Asuman Ozdaglar's research spans the areas of optimization, with emphasis on nonlinear optimization and distributed optimization methods, game theory, network economics, and network optimization and control.

The research in her group focuses on problems that arise in analysis and optimization of large-scale dynamic multiagent networked systems. In recent joint work with professor Daron Acemoglu from the Department of Economics and graduate student Kostas Bimpikis, Professor Ozdaglar has developed game-theoretic models for resource allocation problems in communication networks, with a focus on pricing and investment incentives of providers and implications of competition on network performance. A core objective of this work is to quantify and mitigate the losses that result from lack of centralized regulation. This research is supported by an NSF career grant. Her group also conducts research on social networks, where a group of strategic agents, each with their own private information, interact and exchange information over a network. In joint work with professors Daron Acemoglu and Munther Dahleh and graduate student Ilan Lobel, Professor Ozdaglar has provided a new framework to study the problem of Bayesian (equilibrium) learning over general social networks. This work identifies conditions on network topologies and information structures that lead to equilibrium information aggregation in large networks. This research effort is supported by a competitive NSF grant in human and social dynamics and an Air Force Office of Scientific Research (AFOSR) project. Other recent research, in collaboration with professor Pablo Parrilo and graduate student Noah Stein, involves providing new characterizations of Nash and correlated equilibria in continuous games and developing novel methods for their computation. Her group also focuses on developing novel decentralized optimization algorithms for large-scale networks with explicit performance guarantees. In collaboration with professor Angelia Nedic from the University of Illinois at Urbana–Champaign, professor John Tsitsiklis, and graduate student Alex Olshevsky, she has developed algorithms that can optimize general performance metrics and operate over dynamic networks with time-varying connectivity and imperfect information. This research is supported by the DARPA ITMANET program.

Professor Pablo Parrilo

Professor Pablo Parrilo's research group is focused on optimization, systems, and control, with current emphasis on control and identification of uncertain complex systems, robustness analysis and synthesis, and the development and application of computational tools based on convex optimization and algorithmic algebra.

In recent joint work with student Parikshit Shah, a new framework for the design of distributed controllers and decision-making processes has been developed. The methods are applicable to systems with a structure compatible with a partial order. The algebraic properties of such systems and their associated signal spaces have been developed, to provide intrinsic characterizations of structure-preserving controllers.

In joint work with Professor Ozdaglar and their joint student, Noah Stein, Professor Parrilo is developing computational frameworks of Nash and correlated equilibria for multiplayer games, where the payoff functions are a polynomial function of the players' pure strategies. The methods, and resulting computational techniques, generalize a number of earlier works on low-rank games.

Another research direction is the robustness and stability analysis of continuous and hybrid systems. In joint work with student Amir Ali Ahmadi, a methodology for relaxing the monotonicity requirement of Lyapunov's theorem has been developed. This method significantly enlarges the class of functions that can provide certificates of stability. Both the discrete time case and the continuous time case are covered.

Additionally, in collaboration with colleagues from Caltech and the University of Washington, Professor Parrilo is investing further extensions of the "compressed sensing" techniques that deal with low-rank assumptions as opposed to sparsity. Their results show that a particular "nuclear norm" optimization heuristic provably recovers the minimum-rank matrix in a given affine subspace, provided a certain restricted isometry property holds. Furthermore, this condition holds with overwhelming probability if the equations are randomly chosen and the number of equations is sufficiently large.

Professor Devavrat Shah

Professor Devavrat Shah is involved in interdisciplinary research at the interface of communication networks, statistical inference, and information theory. The primary application area of his research is networks such as Internet routers, peer-to-peer networks like BiTTorrent, and wireless ad hoc and sensor networks. An important aspect of the research effort has been development of practical algorithmic solutions inspired by theoretical understanding.

Algorithms are the essential building blocks of any large network. Successful deployment of a network depends primarily on the possibility of implementing high-performance network algorithms. As an algorithm designer, it is important to provide solutions that can lead to a tunable network architecture to reach the right trade-off between implementation cost and performance. Professor Shah has proposed a novel message-passing-based algorithmic architecture to realize this dream of a network engineer. The key enabling features for designing such an algorithmic architecture are based on recently emerging revolutionary ideas at the interface of statistical physics and artificial intelligence (AI). A distinctive feature of Professor Shah's research has been, in addition to providing practical algorithmic network architecture, in providing theoretical guarantees for the high performance of such algorithms.

Professor Shah's research efforts have not only applied ideas from statistical physics and AI to networks but also brought new insights to these communities. Specifically, his work has brought precise understanding of these novel message-passing algorithms, which remained mysterious for more than a decade, using methods of applied probability, optimization, and combinatorics. This research is primarily supported by an NSF CAREER and NSF Theoretical Foundations grant.

Through the ITMANET DARPA program, Professor Shah has been leading the effort to understand the question "what makes it hard to operate wireless networks very efficiently?" The research efforts have led to a new class of simple co-operative architecture that promises to utilize the wireless medium efficiently in the context of a large network setup.

Recently, through an NSF HSD grant Professor Shah has started an effort to understand the socioeconomic importance of recently emerging large social networks such as Facebook. The initial results seem very promising. During the past year, Professor Shah has collaborated with professors Munther Dahleh, David Gamarnik, Muriel Médard, Asuman Ozdaglar, John Tsitsiklis, Alan Willsky, and Gregory Wornell at MIT as well as with researchers at Microsoft research, IBM research, Bell-Alcatel labs, Stanford University, University of Illinois at Urbana–Champaign, Harvard University, and University College of London.

Professor John Tsitsiklis

Professor John Tsitsiklis works on system modeling, analysis, optimization, and control in possibly stochastic and dynamic environments and in the possible presence of multiple agents with conflicting interests. Research activities have focused on developing methodologies, mathematical tools of broad applicability, and computational methods. Motivating applications for recent work have come from domains as diverse as cancer radiation therapy, direct mail marketing, and sensor networks.

Most of the current research of Professor Tsitsiklis deals with decision making, control, and inference in distributed systems, networked agents, and sensor networks, some of it in collaboration with professors Gamarnik, Ozdaglar, Shah, and Win as well as a number of collaborators outside MIT. Current research includes a theoretical analysis of fundamental coordination problems in multiagent systems, such as consensus and averaging, and an analysis of related models of opinion dynamics and consensus that arise in the context of social networks. Another direction involves the development of a mathematical theory for the effects of different architectures (e.g., different kinds of trees) on the detection performance of large-scale sensor networks.

Two additional, new directions of research involve (1) questions about the stability and performance efficiency of communication networks (in collaboration with Professor Shah) and (2) the development of new formulations and techniques in online learning and adaptive resource allocation, resulting in a major extension of the classical theory on multiarmed bandit problems.

Professor Alan S. Willsky

Professor Alan Willsky leads the Stochastic Systems Group (SSG). The general focus is on developing statistically based algorithms and methodologies for complex problems of information extraction and analysis from signals, images, and other sources of data. The work extends from basic mathematical theory to specific areas of application. Funding for this research comes from sources including AFOSR; the Air Force Research Laboratory; the Office of the Director, Defense Research and Engineering; MIT Lincoln Laboratory; and the Royal Dutch Shell Corporation.

Professor Willsky is involved in two major funding initiatives for the future. In particular, he is the MIT principal investigator on a five-year program being finalized by Royal Dutch Shell. This program will be run through the MIT Energy Initiative, with LIDS acting as the focal point for funding that will also involve other units, including the Departments of Civil and Environmental Engineering and Earth and Planetary Sciences and the Computer Science and Artificial Intelligence Laboratory. The other major initiative that Professor Willsky is spearheading is a substantial collaboration with Los Alamos National Laboratory (LANL) and, in particular, the newly formed Center for Information Science and Technology at LANL. Professor Willsky gave a lead lecture at LANL's recent symposium on information sciences and is helping to define programs that will involve many within LIDS.

With respect to research activities, SSG is investigating how to extend and exploit its methodology for problems involving complex graphical models, such as those that arise in military command and control, mapping from remote sensing data, and monitoring complex systems. SSG's work involves examining complex graphical representations and developing tractable algorithms based on these representations. They continue to have major successes in this area, including new classes of signal and image processing algorithms that have provable performance properties, that can be applied to very large problems in a scalable manner, and that outperform previous methods. Recent applications of these methods are to computer vision, mapping of subterranean surfaces in support of oil exploration, and tracking of multiple vehicles from networks of small sensors. This work has also been extended to a variety of machine learning problems in which tractable models are sought for high-dimensional data and phenomena. A number of the methods that have been developed are being or already have been transitioned to research and engineering organizations including Shell Oil, Lincoln Laboratory, and BAE Systems. This part of SSG's research portfolio has received considerable international attention, as evidenced by a string of best paper awards as well as extensive citations and influence on the work of others in fields ranging from systems and control to chemical engineering to groundwater hydrology.

SSG's work also continues to focus on developing statistically based curve evolution algorithms for the segmentation of imagery and extraction of the geometry of regions of interest from complex multimodal data. Recent accomplishments include machine learning methods that perform segmentation while learning the statistical differences between the regions being segmented, tracking dynamically evolving curves, and capturing the inherent uncertainty in extracted geometry through curve-based Monte Carlo simulation methods. Most recently, and in collaboration with researchers at Shell Oil and Brigham and Women's Hospital, SSG's work has focused on developing algorithms that can take user-supplied guidance (e.g., in the form of partial segmentations of slices through three-dimensional data sets) as well as noninvasive indirect measurements (e.g., gravity anomaly measurements in geophysics or CAT scan data in medical imaging) and use them to guide high-performance three-dimensional shape extraction algorithms. Research in this area has also received considerable recognition, including a recent best paper award.

Professor Moe Win

Professor Moe Win and his graduate students (http://wgroup.lids.mit.edu/) are working on applying mathematical and statistical theories to communication, detection, and estimation problems. Their research focuses on wireless systems and networks and combines three important facets: (1) theoretical analysis for determination of fundamental performance limits, (2) the design of practical algorithms that approach such ultimate limits, and (3) experimentation both for validating and for developing realistic statistical models.

Current research topics include inference in sensor networks, synchronization and interference analysis for ultrawide bandwidth systems, diversity with practical channel estimation, cooperative localization, channel identification, aggregate network interference, and signal processing for space and optical communication systems. Professor Win is also completing a state-of-the-art wideband wireless experimentation facility that enables automated channel measurements with an accuracy and scale far beyond existing systems, allowing him to systematically characterize wideband propagation channels and to develop tractable channel models.

Professor Win maintains dynamic collaborations and partnerships with academia and industry, including the University of Bologna and Ferrara in Italy, National University of Singapore, Nanyang Technological University in Singapore, the Jet Propulsion Laboratory, and Mitsubishi Electric Research Laboratories.

Highlights, Awards, and Events

The 2007–2008 year has been one of continuing accomplishment, activity, and intellectual excitement for LIDS. The Lab hosted many events—notably, weekly Colloquia and the Thirteenth Annual LIDS Student Conference. In addition, LIDS provided some of the funds supporting an international conference on language and statistical analysis. A fourth edition of LIDS's community-oriented magazine—LIDS-ALL—is being readied for the start of academic year 2008–2009, and we completed a thorough examination of our activities and mission, assembling a strategic plan on which we are now beginning to act, including the development of an enhanced website, the institution of an external advisory committee, and the regular hosting of major workshops and symposia in emerging and critical new areas. LIDS's sense of community is strong and is being strengthened through the efforts of all within the community.

Several LIDS students and faculty members have garnered recognition for their work this year:

Professor Robert Berwick's research on birdsong and language was highlighted on the PBS series, NOVA.

Professor Mujdat Cetin, a LIDS visiting research scientist and faculty member at Sabanci University, Istanbul, Turkey, received the 2008 Turkish Academy of Sciences Young Scientist Award.

Junmo Kim, Mujdat Cetin, and Alan S. Willsky received the 2007 Elsevier Signal Processing Journal Best Paper Award for their paper titled "Nonparametric Shape Priors for Active Contour-based Image Segmentation."

Jaime Lien received the 2007 David Adler Memorial Thesis Award for Outstanding Electrical Engineering MEng Thesis from the Department of Electrical Engineering and Computer Science, MIT.

Professor Thomas Magnanti received an honorary doctoral degree from Technion. Professor Magnanti was also awarded the Harold Lardner Prize for International Distinction in Operations Research from the Canadian Operations Research Society.

Professor Sanjoy Mitter won the 2007 Richard E. Bellman Control Heritage Award for contributions to the unification of communication and control, nonlinear filtering and its relationship to stochastic control, optimization, optimal control, and infinite-dimensional systems theory.

Professor Asuman Ozdaglar is the 2008 winner of the Donald P. Eckman Award.

Marco Pavone was one of the three finalists in the best student paper competition at ROBOCOMM 2007.

LIDS alumna Sridevi V. Sarma, Electrical Engineering and Computer Science PhD graduate (February 2006), won two prestigious awards: the Burroughs Wellcome Fund Award and the 2008 L'Oréal USA Fellowships for Women in Science.

Professor Devavrat Shah received the First ACM SIGMETRICS/Performance Rising Star Award.

Yuan Shen and Henk Wymeersch received the Best Paper Award at the 2007 IEEE Wireless Communications and Networking Conference.

Erik Sudderth, a recent LIDS graduate, has been listed as one of the IEEE Intelligent Systems top "Ten to Watch."

Professor John Tsitsiklis received the INFORMS Fellow Award.

Professor Moe Win has been selected as an IEEE Distinguished Lecturer by the IEEE Communications Society.

Future Outlook

During the past year, LIDS has spent considerable time and energy examining its mission and planning for the future. The results of that effort are an even greater sense of purpose and an increasingly energized and enthusiastic community of students, staff, and faculty. LIDS has been and remains an internationally recognized home for cutting-edge and seminal fundamental research and for the education of research and engineering leaders of the future. We have embarked on an ambitious set of activities aimed not only at sustaining this position but also at enhancing it considerably. Our efforts involve the new research initiatives outlined previously that represent major challenges for the future in our increasingly information- and distributed system-dominated world as well as partnerships with other groups at MIT, in industry, and at other leading institutions. We are also engaged in other activities aimed at increasing LIDS's profile within MIT and across the broader community, including sponsoring workshops, invitations to world leaders to spend time with us and deliver high-profile colloquia, and outreach activities to some of our most ardent supporters—namely, those who were students in LIDS in the past and were enriched by their time with us. This is an exceptional cadre of leaders and accomplished researchers and engineers, many of whom have expressed their strong and positive feelings about what LIDS has meant to them, and we are intent on building on this sentiment and extending the LIDS community to once again include them as well.

As the 2007–2008 academic year closes, LIDS stands as a singular organization for innovation and true impact in the information and decision sciences. Our people are energized by an environment that allows them to develop and pursue research and educational activities of great substance, and our intentions are to make things even better and more exciting in the future.

Alan S. Willsky
Acting Director
Edwin Sibley Webster Professor of Electrical Engineering and Computer Science

Munther A. Dahleh
Co-Associate Director
Professor of Electrical Engineering and Computer Science

John N. Tsitsiklis
Co-Associate Director
Professor of Electrical Engineering and Computer Science

More information about the Laboratory for Information and Decision Systems can be found at http://lids.mit.edu/.