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PROFESSIONAL INTERESTS

Statistical pattern recognition, nonparametric estimation, learning theory, information theory, wireless networks, adaptive/hybrid systems, image and video processing, econometrics and finance.

EDUCATION

- **Massachusetts Institute of Technology**, Cambridge, MA 02139
  Ph.D. in Electrical Engineering, June 1991.
  Dissertation: "Problems of Computational and Information Complexity in Machine Vision and Learning." Advisor: Professor S.K. Mitter. GPA 4.9/5.0
- **Stanford University**, Stanford, CA 94305
  M.S. in Electrical Engineering, June 1985.
- **Clarkson University**, Potsdam, NY 13676
  M.S.in Mathematics, May 1985.
  B.S. in Electrical Engineering, May 1984.
  B.S. in Mathematics, May 1983. GPA 3.9/4.0

CURRENT STATUS

- **Associate Dean for Academic Affairs**, School of Engineering and Applied Science, Princeton University. 7/03 - present.
- **Associate Professor**, Dept. of Electrical Engineering, Princeton Univ. 7/97 - present.
- **Affiliated Faculty**, Department of Operations Research and Financial Engineering
- **Affiliated Faculty**, Department of Philosophy

PRIOR PROFESSIONAL EXPERIENCE

- **Princeton University**, Princeton, NJ 08544
  Assistant Professor, Department of Electrical Engineering. 9/91 - 6/97.
- **Susquehanna International Group**, Bala Cynwyd, PA 19004 8/97 - 8/01
  Regular consultant in quantitative research, statistical arbitrage, and analysis of firm-wide stock trading.
- **Flarion Technologies, Inc.**, Bedminster, NJ 07921 6/01 - 8/01
  Visiting researcher. Investigated downlink packet scheduling with quality-of-service requirements and throughput of wireless networks.
- **M.I.T. Lincoln Laboratory**, Lexington, MA 02173 7/85-8/91
  Member of Technical Staff in Laser Radar Measurements Group. Investigated feasibility of laser radars for imaging and discrimination of vehicles in flight.
- **M.I.T.**, Cambridge, MA 02139 9/90-8/91
  Graduate Resident in an undergraduate dormitory. Organized, advised, and provided support (personal, social, academic) for a floor of 42 students.
- **University of Massachusetts**, Boston, MA 1/86-5/86
  As a part-time faculty, taught a course entitled "Introduction to Engineering".

- **Stanford University**, Stanford, CA 94305 4/85-6/85
  Grader for a course entitled "The Fourier Transform and Its Applications".
- **Clarkson University**, Potsdam, NY 13676 8/83-8/84
  Research assistant in the Mathematics department. Developed analytic and numerical solutions to a nonlinear partial differential equation with applications in colloid chemistry.
- **Texas Instruments**, Dallas, TX 75265 5/83-8/83
  Summer Engineering Program. Developed diagnostic software in assembly language for a radar system.

AWARDS AND HONORS

- IEEE Fellow, 2004
- Co-supervised Senior thesis that won MacCracken Award for outstanding Senior thesis in Engineering and Applied Sciences, 2003.
- Faculty advisor for student that won Intel Research Award, 2002-2003.
- Walter Curtis Johnson Prize for Teaching Excellence in Electrical Engineering, 2002.
- Princeton University Sophomore Initiative Grant for enhancement of ELE 201 Introduction to Electrical Signals and Systems, 2002.
- Co-author of paper that won best student paper award at IEEE International Conference on Information Technology, Coding, and Compression, 2001.
- Excellence in Teaching Award from Undergraduate Engineering Council for Introduction to Electrical Signals and Systems course taught Fall 2000.
- Excellence in Teaching Award from Undergraduate Engineering Council for Introduction to Electrical Signals and Systems course taught Fall 1999.
- Co-supervised Senior thesis that won MacCracken Award for outstanding Senior thesis in Engineering and Applied Sciences, 1996.
- Senior Member of IEEE, 1996.
- Princeton University 250th Anniversary Fund for Innovations in Undergraduate Education for development of ELE/PHI 218 Learning Theory and Epistemology, 1996.
- Co-author of paper that won honorable mention for best student paper at Conference on Decision and Control, 1995.
- NSF Young Investigator Award (NYI), 1994.
- Emerson-Keyes Faculty Advancement Award from the School of Engineering and Applied Sciences, Princeton University, 1994.
- Princeton University Research Board Award, 1993-1994.
- Co-supervised Senior thesis that won MacCracken Award for outstanding Senior thesis in Engineering and Applied Sciences, 1993.
- Excellence in Teaching Award from Undergraduate Engineering Council for Image Processing course taught Spring 1993.
- ARO (Army Research Office) Young Investigator Award, 1992.

- NSF Research Initiation Award, 1992.
- Excellence in Teaching Award from Undergraduate Engineering Council for Machine Vision course taught Fall 1991.
- Supervised Senior thesis at M.I.T. which won 2^{nd} prize for best undergraduate thesis in Electrical Engineering, 1987.
- Stanford University Fellowship, 1985.
- Frederica Clarkson Award for outstanding graduating Senior, Clarkson University, 1983.
- Hamlin-Darraugh Award for outstanding Senior in Mathematics Department, Clarkson University, 1983.
- Outstanding Sophomore Award, Mathematics Department, Clarkson University, 1982.

PUBLICATIONS

BOOKS

1. G. Harman and S.R. Kulkarni, *The Nature and Limits of Learning*, under review by various publishers.

JOURNAL PUBLICATIONS

Under Review or In Press

1. A. Reznik, S.R. Kulkarni, S. Verdu, "A 'Small World' Approach to Heterogeneous Networks", submitted to *Communications in Information and Systems.*
2. C.-C. Wang, S.R. Kulkarni, H.V. Poor, "Finite-Dimensional Bounds on Iterative Decoding: Extreme Properties of the BSC and BEC in LDPC Codes", submitted to *IEEE Transactions on Information Theory.*
3. A. Jovicic, P. Viswanath and S.R. Kulkarni, "Upper Bounds to Transport Capacity of Wireless Networks", submitted to *IEEE Transactions on Information Theory.*
4. C.-C. Wang, S.R. Kulkarni, H.V. Poor, "Density Evolution for Asymmetric Memoryless Channels", submitted to *IEEE Transactions on Information Theory.*
5. A.P. George, W.B. Powell, S.R. Kulkarni, "The Statistics of Hierarchical Aggregation for Multiattribute Resource Management", submitted to *INFORMS Journal on Computing.*
6. H. Cai, S.R. Kulkarni, S. Verdú, "Universal Estimation of Entropy and Divergence Via Block Sorting," submitted to *IEEE Transactions on Information Theory.*
7. C.-C. Wang, S.R. Kulkarni, H.V. Poor, "Arbitrary Side Observations in Bandit Problems", submitted to *Annals of Applied Probability.*
8. A. Reznik, S.R. Kulkarni, S. Verdú, "Capacity and Optimal Resource Allocation in the Degraded Gaussian Relay Channel with Multiple Relays", submitted to *IEEE Transactions on Information Theory.*
9. C.-C. Wang, S.R. Kulkarni, H.V. Poor, "Bandit Problems With Side Observations", accepted for publication in *IEEE Transactions on Automatic Control.*
10. S.R. Kulkarni and P. Viswanath, "A Deterministic Approach to Throughput Scaling in Wireless Networks," accepted for publication in *IEEE Transactions on Information Theory.*

Appeared

11. R.J. Radke, P.J. Ramadge, S.R. Kulkarni, T. Echigo, "Efficiently Synthesizing Virtual Video," *IEEE Transactions on Circuits and Systems for Video Technology*, Vol. 13, No. 4, pp. 325-337, April, 2003.
12. S. Sandilya and S.R. Kulkarni, "Principal Curves with Bounded Turn," *IEEE Transactions on Information Theory*, Vol. 48, No. 10, pp. 2789-2793, Oct. 2002.

13. S.R. Kulkarni, S.E. Posner, S. Sandilya, "Data-dependent k_n-NN and Kernel Estimators Consistent for Arbitrary Processes," *IEEE Transactions on Information Theory*, Vol. 48, No. 10, pp. 2785-2788, Oct. 2002.

14. M. Effros, K. Visweswariah, S.R. Kulkarni, S. Verdú, "Universal Lossless Source Coding With the Burrows Wheeler Transform," *IEEE Transactions on Information Theory*, Vol. 48, No. 5, pp. 1061-1081, May 2002.

15. S. Sandilya and S.R. Kulkarni, "Nonparametric Control Algorithms for Nonlinear Fading Memory Systems," *IEEE Transactions on Automatic Control*, Vol. 46, No. 7, pp. 1117-1121, July 2001.

16. K. Visweswariah, S.R. Kulkarni, S. Verdú, "Universal Variable-to-Fixed Length Source Codes," *IEEE Transactions on Information Theory*, Vol. 47, No. 4, pp. 1461-1472, May 2001.

17. P.L. Bartlett, S. Ben David, S.R. Kulkarni, "Learning Changing Concepts by Exploiting the Structure of Change," *Machine Learning*, Vol. 41, No., pp. 153-174, Nov. 2000.

18. K. Visweswariah, S.R. Kulkarni, S. Verdú, "Separation of Random Number Generation and Resolvability," *IEEE Transactions on Information Theory*, Vol. 46, No. 6, pp. 2237-2241, Sept. 2000.

19. K. Visweswariah, S.R. Kulkarni, S. Verdú, "Universal Coding of Nonstationary Sources," *IEEE Transactions on Information Theory*, Vol. 46, No. 4, pp. 1633-1637, July 2000.

20. K. Visweswariah, S.R. Kulkarni, S. Verdú, "Asymptotically Optimal Variable-to-Fixed Length Codes for Markov Sources," *Journal of Combinatorics, Information, and System Sciences*, Vol. 25, 2000.

21. S.R. Kulkarni and G. Lugosi, "Finite Time Lower Bounds for the Two-Armed Bandit Problem," *IEEE Transactions on Automatic Control*, Vol. 45, No. 4, pp. 711-714, April 2000.

22. Y.-P. Tan, D.D. Saur, S.R. Kulkarni, P.J. Ramadge, "Rapid Estimation of Camera Motion from Compressed Video With Application to Video Annotation," *IEEE Transactions on Circuits and Systems for Video Technology*, Vol. 10, No. 1, pp. 133-146, Feb. 2000.

23. M. Vidyasagar and S.R. Kulkarni, "Some Contributions to Fixed-Distribution Learning Theory," *IEEE Transactions on Automatic Control*, Vol. 45, No. 2, pp. 217-234, Feb. 2000.

24. E.K.P. Chong, I.-J. Wang, S.R. Kulkarni, "Noise Conditions for Prespecified Convergence Rates of Stochastic Approximation Algorithms," *IEEE Transactions on Information Theory*, Vol. 45, No. 2, pp. 810-814, March, 1999.

25. G. Morvai, S.R. Kulkarni, A.B. Nobel, "Regression Estimation from an Individual Stable Sequence," *Statistics*, Vol. 33, pp. 99-118, 1999.

26. S.R. Kulkarni and S.E. Posner, "Nonparametric Output Prediction for Nonlinear Fading Memory Systems," *IEEE Transactions on Automatic Control*, Vol. 44, No.1, pp. 29-37, Jan. 1999.

27. S. Di Gennaro, C. Horn, S.R. Kulkarni, P.J. Ramadge, "Reduction of Timed Hybrid Systems," *Discrete Event Dynamic Systems – Theory and Applications*, Vol. 8, No. 4, pp. 343-351, Dec. 1998.

28. S.R. Kulkarni, G. Lugosi, S.S. Venkatesh, "Learning Pattern Classification – A Survey," *IEEE Transactions on Information Theory*, Vo. 44, No. 6, pp. 2178-2206, Oct. 1998.

29. P.L. Bartlett and S.R. Kulkarni, "The Complexity of Model Classes, and Smoothing Noisy Data," *Systems and Control Letters*, Vol. 34, No. 3, pp. 133-140, June 1998.

30. J. Hocherman-Frommer, S.R. Kulkarni, P.J. Ramadge, "Controller Switching Based on Output Prediction Errors," *IEEE Transactions on Automatic Control*, Vol. 43, No. 5, pp. 596-607, May, 1998.

31. H. Schweitzer and S.R. Kulkarni, "Computational Limitations of Model-Based Recognition," *International Journal of Intelligent Systems*, Vol. 13, No. 5, pp. 431-443, May, 1998.

32. K. Visweswariah, S.R. Kulkarni, S. Verdú, "Source Codes as Random Number Generators," *IEEE Transactions on Information Theory*, Vol. 44, No. 2, pp. 462-471, March, 1998.

33. A.B. Nobel, G. Morvai, S.R. Kulkarni, "Density Estimation from an Individual Numerical Sequence," *IEEE Transactions on Information Theory*, Vol. 44, No. 2, pp. 537-541, March, 1998.

34. I.-J. Wang, E.K.P. Chong, S.R. Kulkarni, "Weighted Averaging and Stochastic Approximation," *Mathematics of Control, Signals, and Systems*, Vol. 10, No. 1, pp. 41-60, 1997.

35. P. Bartlett, S.R. Kulkarni, S.E. Posner, "Covering Numbers for Classes of Real-Valued Function," *IEEE Transactions on Information Theory*, Vol. 43, No. 5, pp. 1721-1724, Sept., 1997.

36. S.R. Kulkarni and M. Vidyasagar, "Learning Decision Rules for Pattern Classification Under a Family of Probability Measures," *IEEE Transactions on Information Theory*, Vol. 43, No. 1, pp. 154-166, January, 1997.

37. S.R. Kulkarni and P.J. Ramadge, "Model and Controller Switching Policies Based on Output Prediction Errors," *IEEE Transactions on Automatic Control*, Vol. 41, No. 11, pp. 1594-1604, November, 1996.

38. I.-J. Wang, E.K.P. Chong, and S.R. Kulkarni, "Equivalent Necessary and Sufficient Conditions on Noise Sequences for Stochastic Approximation Algorithms," *Advances in Applied Probability*, Vol. 28, No. 3, pp. 784-801, Sept., 1996.

39. S. Wang, B. Liu, S.R. Kulkarni, "Model-based Reconstruction of Multiple Circular and Elliptical Discs from a Limited Number of Projections," *IEEE Transactions on Image Processing*, Vol. 5, No. 9, pp. 1386-1390, Sept., 1996.

40. W.C. Karl, S.R. Kulkarni, G.C. Verghese, and A.S. Willsky,"Local Tests for Consistency of Support Hyperplane Data," *Journal of Mathematical Imaging and Vision*, Vol. 6, No. 2-3, pp. 249-267, June, 1996.

41. W. Lam and S.R. Kulkarni, "Extended Synchronizing Codewords for Binary Prefix Codes," *IEEE Transactions on Information Theory*, Vol. 42, No. 3, pp. 984-987, May, 1996.

42. S.R. Kulkarni and C. Horn, "An Alternative Proof for Convergence of Stochastic Approximation Algorithms," *IEEE Transactions on Automatic Control*, Vol. 41, No. 3, pp. 419-424, Mar., 1996.

43. S.R. Kulkarni and O. Zeitouni, "A General Classification Rule for Probability Measures," *Annals of Statistics*, Vol. 23, No. 4, pp. 1393-1407, 1995.

44. S.R. Kulkarni and S.E. Posner, "Rates of Convergence of Nearest Neighbor Estimation under Arbitrary Sampling," *IEEE Transactions on Information Theory*, Vol. 41, No. 4, pp. 1028-1039, July, 1995.

45. S.R. Kulkarni and D.N.C. Tse, "A Paradigm for Class Identification Problems," *IEEE Transactions on Information Theory*, Vol. 40, No. 3, pp. 696-705, May, 1994.

46. R.M. Dudley, S.R. Kulkarni, T.J. Richardson, O. Zeitouni, "A Metric Entropy Bound is Not Sufficient for Learnability," *IEEE Transactions on Information Theory*, Vol. 40, No. 3, pp. 883-885, May, 1994.

47. S.R. Kulkarni, S.K. Mitter, T.J. Richardson, J.N. Tsitsiklis, "Local Versus Non-local Computation of Length of Digitized Curves," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 16, No. 7, pp. 711-718, July, 1994.

48. S.R. Kulkarni, S.K. Mitter, J.N. Tsitsiklis, and O. Zeitouni, "PAC Learning With Generalized Samples and an Application to Stochastic Geometry," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 15, No. 9, pp. 933-942, Sept. 1993.

49. S.R. Kulkarni, S.K. Mitter, J.N. Tsitsiklis, "Active Learning Using Arbitrary Binary Valued Queries," *Machine Learning*, Vol. 11, No. 1, pp. 23-35, April 1993.

50. A.S. Lele, S.R. Kulkarni, A.S. Willsky, "Convex Polygon Estimation from Support Line Measurements and Applications to Target Reconstruction from Laser Radar Data," *Journal of the Optical Society of America A*, Vol. 9, No. 10, pp. 1693-1714, October 1992.

51. S.R. Kulkarni, and O. Zeitouni, "Can One Decide the Type of the Mean from the Empirical Measure?," *Statistics & Probability Letters*, Vol. 12, No. 4, pp. 323-327, October 1991.

52. F.K. Knight, S.R. Kulkarni, R.M. Marino, J.K. Parker, "Tomographic Techniques Applied to Laser Radar Reflective Projections," *The Lincoln Laboratory Journal*, Vol. 2, No. 2, pp. 143-158, Summer 1989.

53. J.K. Parker, et al., "Reflective tomography: images from range-resolved laser radar measurements," *Applied Optics*, Vol. 27, No. 13, pp. 2642-2643, July 1988.

54. E. Barouch, and S. R. Kulkarni, "Exact Solution of the Poisson-Boltzmann Equation for Two Spheres with Fixed Surface Potentials," *Journal of Colloid and Interface Science*, Vol. 112, No. 2, pp. 396-402, August 1986.

BOOK CHAPTERS

1. S.R. Kulkarni and S.E. Posner, "Universal Output Prediction and Nonparametric Regression for Arbitrary Data," in *Learning, Control and Hybrid Systems*, edt. by Y. Yamamoto and S. Hara, Lecture Notes in Control and Information Sciences Vol. 241, Springer-Verlag, pp. 254-268, 1999.

2. J. Hocherman-Frommer, S.R. Kulkarni, P.J. Ramadge, "Controller Switching Based on Output Predictions," in *Learning, Control and Hybrid Systems*, edt. by Y. Yamamoto and S. Hara, Lecture Notes in Control and Information Sciences Vol. 241, Springer-Verlag, pp. 135-149, 1999.

3. S.R. Kulkarni and P.J. Ramadge, "On the Performance and Complexity of a Class of Hybrid Controller Switching Policies," in *Control Using Logic-Based Switching*, edt. by S. Morse, Lecture Notes in Control and Information Sciences Vol. 222, Springer-Verlag, pp. 248-261, 1997.

4. S.R. Kulkarni, "A Review of Some Extensions to the PAC Learning Model," in *Learning and Geometry: Computational Approaches*, edt. by C. Smith and D. Keuker, pp. 43-64, Birkhauser, Boston, 1996.

5. S.R. Kulkarni, "A Review of Some Extensions to the PAC Learning Model," in *Computing and Intelligent Systems*, edt. by S.S. Keerthi, Y. Narahari, N. Viswanadham, Tata McGraw-Hill, 1994.

6. S.R. Kulkarni, S.K. Mitter, T.J. Richardson, "An Existence Theorem and Lattice Approximations to a Variational Problem," *Signal Processing, Part I: Signal Processing Theory*, IMA Vol. 22, edt. by Auslander et al., Springer-Verlag, pp. 189-210, 1990.

CONFERENCES

1. A. Jovicic, S.R. Kulkarni, P. Viswanath, "Upper Bounds to Transport Capacity in Wireless Networks", *42nd IEEE Conference on Decision and Control*, December, 2003.

2. C.-C. Wang, S.R. Kulkarni, H.V. Poor, "Arbitrary Side Observations in Bandit Problems", *42nd IEEE Conference on Decision and Control*, December, 2003.

3. C.-C. Wang, S.R. Kulkarni, H.V. Poor, "Density Evolution for Asymmetric Memoryless Channels", *3rd International Symposium on Turbo Codes and Related Topics*, Brest, France, Sept., 2003.

4. S.R. Kulkarni and P. Viswanath, "Throughput Scaling for Heterogeneous Networks," *Proc. International Symposium on Information Theory*, Yokohama, Japan, June 2003.

5. C.-C. Wang, S.R. Kulkarni, H.V. Poor, "Bandit Problems With Side Information", *41st IEEE Conference on Decision and Control*, December, 2002.

6. A. Reznik, S.R. Kulkarni, S. Verdú, "Capacity and Optimal Resource Allocation in the Degraded Gaussian Relay Channel with Multiple Relays," *40th Allerton Conference on Communication, Control, and Computing*, Sept. 2002.

7. H. Cai, S.R. Kulkarni, S. Verdú, "Universal Estimation of Entropy and Divergence Via Block Sorting," *Proc. International Symposium on Information Theory*, Lausanne, Switzerland, July 2002.

8. S.R. Kulkarni and P. Viswanath, "A Deterministic View of Throughput Scaling in Wireless Networks," *Proc. International Symposium on Information Theory*, Lausanne, Switzerland, July 2002.

9. R.J. Radke, P.J. Ramadge, S.R. Kulkarni, T. Echigo, "Using View Interpolation for Low Bit Rate Video," *IEEE International Conference on Image Processing*, Thessoloniki, Greece, October 2001.

10. R.J. Radke, V. Zogorodnov, S.R. Kulkarni, P.J. Ramadge, "Estimating Correspondence in Digital Video," *IEEE International Conference on Information Technology, Coding, and Compression*, Las Vegas, Nevada, April, 2001.

11. R.J. Radke and S.R. Kulkarni, "An Integrated Matlab Suite for Introductory DSP Education," *1st IEEE Signal Processing Education Workshop*, Hunt, Texas, October 2000.

12. R.J. Radke, P.J. Ramadge, S.R. Kulkarni, T. Echigo, S. Iisaku, "Recursive Propagation of Correspondences with Applications to the Creation of Virtual Video," *IEEE International Conference on Image Processing*, Vancouver, Canada, September 2000.

13. S. Sandilya and S.R. Kulkarni, "Principal Curves With Bounded Turn," *Proc. International Symposium on Information Theory*, June 2000.

14. K. Visweswariah, S.R. Kulkarni, S. Verdú, "Output Distribution of the Burrows Wheeler Transform," *Proc. International Symposium on Information Theory*, p. 53, June 2000.

15. S. Sandilya and S.R. Kulkarni, "Nonparametric Control Algorithms for Nonlinear Fading Memory Systems," *Proc. 38th IEEE Conference on Decision and Control*, pp. 4613-4618, Phoenix, AZ, Dec. 1999.

16. Y.-P. Tan, S.R. Kulkarni, P.J. Ramadge, "A Framework for Measuring Video Similarity and Its Application to Video Query by Example," *International Conference on Image Processing*, Kobe, Japan, 1999.

17. K. Visweswariah and S.R. Kulkarni, "Universal Variable-to-Fixed Length Source Codes for Markov Sources," *Proc. International Symposium on Information Theory*, p. 48, Aug., 1998.

18. A.B. Nobel, G. Morvai, S.R. Kulkarni, "Density Estimation from an Individual Numerical Sequence," *Proc. International Symposium on Information Theory*, p. 355, Aug., 1998.

19. S.R. Kulkarni, S.E. Posner, S. Sandilya, "Data-dependent k_n-NN Estimators Consistent for Arbitrary Processes," *Proc. International Symposium on Information Theory*, p. 388, Aug., 1998.

20. K. Visweswariah, S. Kulkarni, S. Verdú, "Separation of Random Number Generation and Resolvability," *Proc. of the Thirty-Sixth Allerton Conference on Communication, Control and Computing*, Allerton, IL, Sept., 1998.

21. K. Visweswariah, S. Kulkarni, S. Verdú, "Worst Case Bounds on Universal Variable-to-Fixed Length Source Codes," *DIMACS Workshop on Codes and Trees*, NJ, Oct., 1998.

22. Y.-P. Tan, S.R. Kulkarni, and P.J. Ramadge, "The instability of Planar Mosaicking," *Proc. 10th Yale Workshop on Adaptive and Learning Systems*, Yale University, pp. 147-152, June 10-12, 1998.

23. S.R. Kulkarni and G. Lugosi, "Minimax Lower Bounds for the Two-Armed Bandit Problem," *Proc. 35th Conference on Decision and Control*, Dec., 1997.

24. I.-J. Wang, E.K.P. Chong, S.R. Kulkarni, "On Conditions for Convergence Rates of Stochastic Approximation Algorithms," *Proc. 35th Conference on Decision and Control*, Dec., 1997.

25. J. Hocherman-Frommer, S.R. Kulkarni, P.J. Ramadge, "Controller Switching Based on Output Prediction Errors," *Proc. 35th Conference on Decision and Control*, Dec., 1997.

26. K. Visweswariah, S.R. Kulkarni, S. Verdú, "Source Codes as Random Number Generators," *Proc. International Symposium on Information Theory*, Ulm, Germany, June, 1997.

27. S. Sandilya and S.R. Kulkarni, "Deterministic Sufficient Conditions for Convergence of Simultaneous Perturbation Stochastic Approximation Algorithms," *Ninth INFORMS Applied Probability Conference*, Boston, MA, June, 1997.

28. C. Horn and S.R. Kulkarni, "A Parameterized Kushner-Clark Condition for Stochastic Approximation Algorithms," *Ninth INFORMS Applied Probability Conference*, Boston, MA, June, 1997.

29. D.D. Saur, Y.-P. Tan, S.R. Kulkarni, P.J. Ramadge, "Automated Analysis of Structured Video," *IS&T/SPIE Symposium of Electronic Imaging '97:* Storage and Retrieval for Image and Video Databases, San Jose, CA, June, 1997.

30. K. Visweswariah, S. Kulkarni, and S. Verdú, "The Lempel-Ziv algorithm as a Random Number Generator," *Proc. International Conference on Combinatorics, Information Theory and Statistics*, (Third Conference of the Forum for Interdisciplinary Mathematics), p. 88, University of Southern Maine, Portland, Maine, July 18-20, 1997.

31. P. Bartlett and S.R. Kulkarni, "Complexity of Model Classes and Smoothing Noisy Observations," *Proc. 35th Conference on Decision and Control*, Dec., 1996.

32. I-J. Wang, E.K.P. Chong, S.R. Kulkarni, "Weighted Averaging and Stochastic Approximation," *Proc. 35th Conference on Decision and Control*, Dec., 1996.

33. Y.-P. Tan, P.J. Ramadge, S.R. Kulkarni, "Extracting Good Features for Motion Estimation," *Proc. International Conference on Image Processing*, Sept., 1996.

34. P.L. Bartlett, S. Ben David, S.R. Kulkarni, "Learning Changing Concepts by Exploiting the Structure of Change," *Proc. Ninth Annual Conference on Computational Learning Theory*, June, 1996.

35. J. Hocherman-Frommer, S.R. Kulkarni, P.J. Ramadge, "Time Varying Switched Control Based on Output Prediction Errors," *Proc. 34th Conference on Decision and Control*, pp. 2316-2317, Dec., 1995.

36. S.R. Kulkarni and P.J. Ramadge, "Prediction Error Based Controller Selection Policies," *Proc. 34th Conference on Decision and Control*, pp. 3211-3216, Dec., 1995.

37. S.R. Kulkarni and P.J. Ramadge, "On the Existence and Complexity of Convergent On-line Decision Rules," *Proc. 34th Conference on Decision and Control*, pp. 3022-3027, Dec., 1995.

38. S.R. Kulkarni and S.E. Posner, "Universal Prediction of Nonlinear Systems," *Proc. 34th Conference on Decision and Control*, pp. 4024-4029, Dec., 1995.

39. S.R. Kulkarni and C.S. Horn, "Necessary and Sufficient Conditions for Convergence of Stochastic Approximation Algorithms Under Arbitrary Disturbances," *Proc. 34th Conference on Decision and Control*, pp. 3843-3845, Dec., 1995.

40. I.-J. Wang, E.K.P. Chong, S.R. Kulkarni, "On the Equivalence of Some Noise Conditions for Stochastic Approximation Algorithms," *Proc. 34th Conference on Decision and Control*, pp. 3849-3856, Dec., 1995.

41. J.S. Lerman and S.R. Kulkarni, "Convex Set Estimation from Noisy Point Probe Measurements," *Proc. International Conference on Image Processing*, Oct., 1995.

42. Y.-P. Tan, S.R. Kulkarni, P.J. Ramadge, "A New Method for Camera Motion Parameter Estimation," *Proc. International Conference on Image Processing*, Oct., 1995.

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45. S.E. Posner and S.R. Kulkarni, "Nonparametric Regression Estimation for Arbitrary Random Processes," *Proc. International Symposium on Information Theory*, p. 251, Sept., 1995.

46. S.R. Kulkarni and O. Zeitouni, "On the Existence of Strongly Consistent Rules for Estimation and Classification," *Proc. International Symposium on Information Theory*, p. 255, Sept., 1995.

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SUMMARY OF RESEARCH ACTIVITIES AND ACCOMPLISHMENTS

Prior to 1997, my work was focused on several problems in statistical pattern recognition and learning – specifically, on PAC learning, nonparametric regression, composite hypothesis testing, and stochastic approximation. Since 1997, I have continued to make new contributions in several of these areas, and also started work in other directions, notably in information theory and wireless networks.

The main focus of my research has been the study of and interplay between learning and information. My work has contributed to the theoretical foundations in these areas, helping to delineate the limits of what can and cannot be achieved. Understanding the theoretical foundations can also drive new advances and allow a more principled approach to the design and analysis of practical systems and algorithms.

The primary goal of my own work has been to weaken assumptions required in the analysis of various problems in statistical pattern recognition, learning, information theory, estimation, and control, thereby broadening the domain of applicability of the results. Early work in these and other areas has generally started by assuming that a precise model for the observed data or system is known. However, this is quite unrealistic in many applications, and so as work progressed in each field, more emphasis was placed on cases in which models for the observed data are not known exactly. A first step in this direction is to assume that the uncertainty is parametric in nature — that is, assume that the system or probability distributions generating the data are known except for some small number of parameters. Although this is an improvement, it is often still an unrealistic assumption in applications. The more realistic case involves nonparametric model uncertainty with perhaps only mild regularity assumptions. This progression from assuming exact models to parametric uncertainty to nonparametric uncertainty took place independently in several disciplines, and nonparametrics continues to be a focus of attention. My work has been aimed at further relaxing assumptions on the data distributions and/or better understanding the role and tradeoffs of such assumptions generally within a nonparametric setting.

Among other contributions, one conceptual approach that has been developed in several of my papers is the idea of analyzing arbitrary (or individual) data sequences. The key idea is that certain problems can be analyzed by an elementary deterministic approach, to obtain results for every fixed sequence. Then statements for probabilistic models can be obtained by simply checking that the deterministic conditions are satisfied along sample paths of the probabilistic model. Besides offering a new and elementary approach to various problems with more general results, this also has the advantages of getting to the fundamental conditions that allow results for many probabilistic models to be obtained as special cases with a unified approach.

Some of my accomplishments in these areas are briefly summarized below, focusing primarily on those results obtained after receiving tenure. More detail on these as well as other areas in which I have worked (both before and after receiving tenure) can be found in various journal and conference papers in my complete list of publications.

Nonparametric Regression and Universal Output Prediction

The problems of statistical pattern recognition and/or nonparametric regression estimation can be formulated as follows. We are given a set of training pairs $(X_1, Y_1), \ldots, (X_{n-1}, Y_{n-1})$, and an observation X_n. Our task is to provide an estimate for the label Y_n associated with X_n without knowledge of the distributions generating the data. Much fundamental work in this area has been done by Barron, Cover, Devroye, Gyorfi, Stone, and others. Most work on regression estimation considers the case in which the data is independent and identically distributed. I have been investigating nonparametric regression estimation under arbitrary processes.

Prior to 1997, with my student S.E. Posner (now at Goldman Sachs), we obtained time-average consistency results that eliminate the need for i.i.d./stationarity assumptions on the data (e.g., see [1]).

We also extended these ideas to provide a universal nonparametric output predictor for an unknown system based on nearest neighbor estimators (e.g., see [2]). Our algorithms are "universal" in the sense that they predict asymptotically well for every bounded input sequence, every disturbance sequence in certain classes, and every system that is bounded, continuous, and asymptotically time-invariant, causal, with fading memory. The predictor uses only previous input and noisy output data of the system without any knowledge of the structure of the system. Under additional smoothness conditions we have been able to provide rates of convergence for our scheme.

In work after 1997, we introduced special data-dependent estimators that provide consistent estimates (*without* the need for time-averaging) for arbitrary processes [3]. In other related work, we studied density estimation and regression for individual sequences [4, 5]. These results provide general consistency results from which various classical results for random data can be obtained as special cases. We also further extended the connection between regression and systems by considering nonparametric control [6]. Our results in this area complement work on system identification by others (e.g., see [8, 7, 9, 10, 11]) and some recent work in time series estimation (e.g., see [12]).

Stochastic Approximation

The idea of stochastic approximation is to provide sequential estimates for parameters (e.g., zeros or maxima of functions) from noisy observations. In my early work in this area before 1997, I developed with C. Horn (a former Ph.D. student of Prof. Ramadge) a new approach for analyzing stochastic approximation algorithms that is deterministic, remains in a discrete-time setting and is very elementary [13]. Furthermore, the results obtained were the first to provide necessary and sufficient conditions for arbitrary gain sequences in a Hilbert space setting, and also introduced a new form and parameterized extension of the well known Kushner-Clark condition. In related work, with I.-J. Wang and E. Chong, we showed the equivalence of various conditions that have been used in stochastic approximation [14]. Hence, this showed that the well known Kushner-Clark conditions, as well as other more recent conditions that were thought to be weaker, are all in fact necessary and sufficient for convergence.

After 1997, in continued work in this area, we investigated averaging techniques that have been recently attracting much interest. We gave a new perspective on averaging by showing that averages of stochastic approximation iterates converge under weaker conditions on the noise sequence (than those needed without averaging). Again, our analysis technique is deterministic and quite elementary [15]. We have also extended this approach to obtain deterministic and tight statements on rates of convergence [16]. For a prespecified rate of convergence, we have determined the exact conditions on the noise sequence for which the specified convergence rate is attained.

Uniformly Consistent Estimation/PAC Learning

PAC (Probably Approximately Correct) learning refers to finding uniformly good estimators in classification and regression problems when the decision rules are required to belong to a known class of decision rules. Some of my early work in this area prior to 1997 was among the first to draw connections with covering numbers, which was later further studied and extended by a number of authors (e.g., see [19]). For example, with R. Dudley, et al., we resolved a conjecture that had been open for several years regarding learnability for a class of distributions [17], showing that a uniform metric entropy bound is *not* sufficient for learning with respect to a class of distributions. With M. Vidyasagar, I have obtained results showing that the two extreme cases of fixed distribution and distribution-free learning are rather generic [18]. That is, classes with parametric uncertainty effectively behave as in the fixed distribution case, while classes with nonparametric uncertainty behave as in the distribution-free case.

In more recent work (after 1997), I have made further contributions to this area. With M. Vidyasagar we obtained general results for fixed distribution learning that extend and subsume previous known results in this area [21]. With P. Bartlett and S.E. Posner, we have used results from learning theory to obtain bounds on covering numbers for real-valued function classes [20]. Also, with P. Bartlett, I studied a smoothing problem via a deterministic analysis that gives necessary and sufficient conditions on model

classes to allow smoothing of noisy data [22]. These results begin to provide a deterministic analysis of PAC type problems. They also begin to provide connections with problems in output prediction discussed above and are reminiscent of results in system identification (e.g. [24] and references therein). Other recent work, I've done in this area considers the case of dynamic (or changing) concepts [23], which provides another perspective on connections between results in learning theory and models considered in systems theory.

Information Theory

After 1997, an entirely new direction I began studying concerns several information theoretic problems in the area of source coding. With S. Verdú and K. Visweswariah (a jointly supervised Ph.D. student), we considered the problem of random bit generation from an information-theoretic perspective [25]. We showed that when appropriately formulated, the output of good source codes are random bits. In particular, universal source codes can be used as universal random bit generators. We also obtained a separation result for random number generation and resolvability [26]. We have also obtained interesting results on two other problems of interest. There has been a great deal of work on fixed-to-variable source codes (e.g., Lempel-Ziv coding), but much less on variable-to-fixed codes, for which we have shown universal coding results [27, 28]. Likewise, although most analyses of source coding deal with stationary sources, we have obtained results on universal coding of non-stationary sources [29].

More recently, we have begun to study data compression based on the Burrows-Wheeler transform, which has been observed in recent years to outperform Lempel-Ziv based compression. Our work has shown such schemes to be universal and has provided an analysis of the output statistics of the Burrows-Wheeler transform [30]. We are also studying the problem of estimating the entropy and divergence of two unknown sources based on realizations from the two sources. We have developed algorithms based on the Burrows-Wheeler transform that appear to offer significant improvements over existing methods [31, 32]. We are continuing efforts in this promising direction on theory, algorithms, and applications.

Wireless Networks and Network Information Theory

Another new direction I have very recently (in 2001) become interested in is the area of wireless communications (and in particular, wireless networks), and I spent a portion of the summer of 2001 with Flarion Technologies, Inc. Although I have just recently started working in this area, I have already made contributions on two problems on which I am continuing work.

One problem we are studying is to understand how throughput of an all wireless system (or a wireless ad-hoc network) scales with space and the number of users. In [33], the authors show that regardless of the initial location of the nodes and traffic pattern in a fixed area, the throughput of a network in bit-meters per second cannot grow faster than $\sqrt{n}$, and for a very special arrangement of nodes and traffic pattern a throughput $\sqrt{n}$ can be achieved. They also show that if the nodes are randomly placed in a fixed area and with a random traffic pattern, the throughput grows as $\sqrt{n}/\sqrt{\log n}$. In [34, 35], we introduce a deterministic approach, and obtain a general result on achievable throughput in terms of certain properties of the node locations and traffic pattern. We show that $\sqrt{n}$ throughput can in fact be achieved for a broad class of node arrangements and traffic patterns. Our results are quite general, can easily recover some previous results, and can also be used to obtain throughput results for non-i.i.d. node distributions. In further work in this direction [39], we have studied throughput scaling for heterogenous (or hybrid) networks consisting of a number of wireless nodes together with access to a wired infrastructure. Our results have show that under certain assumptions, at least $\sqrt{n}$ access points are needed for the wired infrastructure to improve the throughput scaling. These are the first results of this type and begin to characterize the tradeoff between interference-limited wireless communication and access-limited communication using the wired infrastructure.

A second problem we are studying is to investigate the Shannon capacity region of networks. While the general problem is extremely difficult, it is possible to obtain results for specially structured sub-problems. In particular, by building on results in [36] and [37], we recover a result of [38] on the capacity

region of a Gaussian channel with multiple relay stages. Our inductive argument shows how a coding strategy can be built recursively.

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- **Princeton University**, University Research Board AR Tuition Award. Principal Investigator. Tuition for S.E. Posner for '93-'94 academic year.

- **National Science Foundation**, Group Travel Grant. Workshop on Computing and Intelligent Systems, Dec. 20-22, 1993, Bangalore India. Principal Investigator. $10,000 for the period 11/1/93 - 10/31/94.

- **Army Research Office**, Group Travel Grant. Workshop on Computing and Intelligent Systems, Dec. 20-22, 1993, Bangalore India. Principal Investigator. $15,000 for the period 12/1/93 - 5/31/94.

- **Siemens Corporate Research**, Electronic Eye Project. Co-Principal Investigator (with several Princeton faculty). $200,000 per year 11/1/93 - 10/31/95

- **BMFT (German Ministry)**, Artificial Eye Study. Co-Principal Investigator (with several Princeton faculty and Siemens Corporate Research).

- **National Science Foundation**, Small Scale Infrastructure Program. Experimental Facilities for Application-Directed System Synthesis. Co-principal Investigator (with W. Wolf, A. Wolfe, S. Malik, S.Y. Kung, B. Liu). $1,153,584 for the period 10/1/92 - 9/30/97.

- **Army Research Office**, Young Investigator Award. Extending and Unifying Formal Models in Machine Learning. Principal Investigator. $130,000 for the period 8/1/92 - 7/31/95.

- **National Science Foundation**, Research Initiation Award Extensions of Learning Models and Applications to Signal Processing and Geometric Reconstruction. Principal Investigator. $60,000 for the period 7/1/92 - 6/30/94.

SUMMARY OF TEACHING ACTIVITIES AND ACCOMPLISHMENTS

COURSES TAUGHT BEFORE 1997

- **PHI/ELE 218 Learning Theory and Epistemology**
  A cross-listed course between the Departments of Philosophy and Electrical Engineering. Taken by students at a variety of levels with a variety of backgrounds. Co-taught with Prof. Gil Harman in Spring 1997.
- **ELE 481 Machine Vision**
  A senior level Electrical Engineering course. Taught Fall 1991.
- **ELE 488 Image Processing and Transmission**
  An upper-level undergraduate course, taken primarily by Electrical Engineering majors. Taught Spring 1992, Spring 1993, Spring 1994, Spring 1995.
- **ELE 530 Theory of Detection and Estimation**
  A graduate-level course taken primarily by students in Electrical Engineering with an interest in signals, communications, and control. Taught Spring 1994.
- **ELE 535 Machine Learning and Pattern Recognition**
  Taught Fall 1992, Fall 1993, Spring 1996, Spring 1997.
- **COS 598b/ELE 539b Open Problems in Human and Machine Intelligence**
  A graduate level topics course. Co-taught with Eric Ristad in Spring 1992.

COURSES TAUGHT AFTER 1997

- **ELE 201 Introduction to Electrical Signals and Systems**
  A sophomore-level required Electrical Engineering course. Taught Fall 1999, Fall 2000, Fall 2001, Fall 2002, Fall 2003.
- **PHI/ELE 218 Learning Theory and Epistemology**
  A cross-listed course between the Departments of Philosophy and Electrical Engineering. Taken by students at a variety of levels with a variety of backgrounds. Co-taught with Prof. Gil Harman in Spring 1997, Fall 1997, Spring 1999, Spring 2001, Spring 2003.
- **ELE 222 Earth (Silicon), Wind (Wireless), and Fire (Fiber-optics): Technologies for the Non-Technologist**
  A course designed to introduce non-electrical engineering majors to important technological areas within electrical engineering. Co-taught with Profs. Sharad Malik and James Sturm in Fall 2002.
- **ORF 534 Financial Engineering**
  A graduate-level course in the Department of Operations Research and Financial Engineering. Taught Spring 2000, Spring 2001.
- **ORF 535 Statistical Analysis of Large Financial Databases**
  A graduate-level course in the Department of Operations Research and Financial Engineering. Taught Spring 2002.

HIGHLIGHTS

- Have taught a broad range of courses and have taught or co-taught courses in four departments (Electrical Engineering, Computer Science, Philosophy, and Operations Research & Financial Engineering).
- Have received four E-Council Excellence in Teaching Awards for three different courses I have taught:
  – For ELE 481 Machine Vision taught Fall 1991 (my first semester here).
  – For ELE 488 Image Processing taught Spring 1993.
  – For ELE 201 Introduction to Electrical Signals and Systems taught Fall 1999.
  – For ELE 201 Introduction to Electrical Signals and Systems taught Fall 2000.
- Significant overhaul of curriculum and labs in ELE 201 Introduction to Electrical Signals and Systems. During my time teaching this course, I have attracted a wide range of students to this course. Previously the course was taken only by electrical engineering majors. Now, in addition to electrical engineers, over half the students major in other departments, including a number from the humanities and social sciences. Furthermore, the course is now available to qualified high school students through the High School Program run through the Teacher Preparation Program.
- Introduced a new undergraduate course on Machine Vision (ELE 481) approved as a regular senior level course in electrical engineering.
- Further developed an undergraduate course on Image Processing (ELE 488 – formerly ELE 487) which had previously been taught only twice in our department.
- Introduced a new graduate course on Machine Learning and Pattern Recognition (ELE 535) approved as a regular graduate course in electrical engineering.
- Introduced a new distribution course on "Learning Theory and Epistemology" jointly with Prof. Harman of the Department of Philosophy. This joint EE/Philosophy course is the only course of its kind in the country that I am aware of, and was also this department's first foray into curriculum outreach beyond the E-Quad. Recently other EE courses have followed this lead (ELE 330, 391, 101, 222).
- Since I joining department in Fall 1991, have supervised or co-supervised over 80 independent semester projects. Several of these have appeared as conference papers, and one has resulted in a journal paper. Also, three of these projects have won the Calvin-Dodd MacCracken Award for best undergraduate thesis in engineering and applied sciences in May 1993, May 1996, and May 2003.
- Have consistently received excellent evaluations and feedback from student course evaluations. I have included a summary of my teaching evaluation scores obtained from the registrar on the following page. The written responses from the students have also been overwhelmingly positive.

ADVISING

PH.D. STUDENTS GRADUATED

- Dr. S. Eli Posner. June, 1995. *Nonparametric Estimation, Regression, and Prediction, Under Minimal Regularity Conditions.* Currently with Goldman Sachs.
- Prof. Yap-Peng Tan (co-supervised with P. Ramadge). June, 1997.
  Digital Video Analysis and Manipulation. Currently with the Department of Electrical and Electronic Engineering, Nanyang Technological University, Singapore.
- Dr. Karthik Visweswariah (co-supervised with S. Verdú). Sept., 1999.
  Topics in the Analysis of Universal Compression Algorithms. Currently with IBM T.J. Watson Research Center.
- Dr. Sathyakama Sandilya. Nov., 2000.
  Topics in Nonparametric Statistics. Currently with Siemens Corporate Research.
- Prof. Richard Radke (co-advised with P. Ramadge). June, 2001.
  Estimation Problems in Digital Video. Currently with the Department of Electrical and Computer Engineering, RPI.

CURRENT PH.D. STUDENTS

- Haixiao (Andrew) Cai (co-advising with S. Verdú) — fifth year.
- Alex Reznik (co-advising with S. Verdú) — fifth year.
- Chih-Chun Wang (co-advising with H.V. Poor) — fourth year.
- Abraham George (ORFE student, co-advising with W. Powell) — third year.
- Joel Predd (co-advising with H.V. Poor) — third year.
- Sung-Hyun Son (co-advising with S.C. Schwartz) — third year.
- Qing Wang (co-advising with S. Verdú) — second year.
- Aurelie Lozano — second year.

MASTER'S STUDENTS

- Shinichi Kozu. M.S. May 1993. Now with NEC, Japan.
- Song Wang (co-supervised with B. Liu). M.S., June 1995. Joined Data Physics Corporation.
- Daniel Newman. M.S., June 1995. Now with ViaSat.
- Qingyi Zhang (co-supervised with P. Ramadge). M.S., November 2000.
- Robert Miller (co-supervised with P. Ramadge). M.S., August 2001. Now with Booz-Allen-Hamilton.

GRADUATE ACADEMIC ADVISOR

For first year ISS students:

- Minerva Yeung '92-'93
- Andrew McKellips '93-'94
- Jei Gui '95-'96
- Xin Li '96-'97
- Boonchai Sriponpaew '97-'98
- Husheng Li '00-'01
- Sung-Hyun Son '01-'02
- Qiang Huang '01-'02
- Senem Velipasalar '02-'03
- Lan Dong '03-'04

THESIS READER

1. Wai-Man Lam (advisor: A. Reibman), May '92
2. Kostantinos Diamantaras (advisor: S.Y. Kung), June '92
3. Mark Goudreau (advisor: S.Y. Kung), May '93
4. William Lynch (advisor: B. Liu, A. Reibman), May '93
5. Peyman Milanfar, a Ph.D. student of Prof. A. Willsky at M.I.T., June '93
6. Sridhar Vembu (advisor: S. Verdú), Mar. '94
7. Pushpak Bhattacharyya, a Ph.D. student at I.I.T., Bombay, Mar. '94
8. Jung-Woo Lee (advisor: B. Dickinson), April '94
9. Robert Crow (advisor: S. Schwartz), June '94
10. Ellen Farrey (advisor: D. Dickinson), Aug. '94
11. Nigel Lee (advisor: S. Schwartz), Nov. '94
12. Wei Ding (advisor: B. Liu), April '95
13. Charles Horn (advisor: P. Ramadge), June '95
14. Wee Sun Lee, Ph.D. student at Australian National University, April '96
15. Minerva Yeung (advisor: B. Liu), July, '96
16. Tsungnan Lin (advisor: S.Y. Kung), Sept. '96
17. Shang-Hung Lin (advisor: S.Y. Kung), Sept. '96
18. Wenjun Zeng (advisor: B. Liu), April '97.
19. Yun-Ting (Claire) Lin (advisor: S.Y. Kung), Dec. '97.
20. Andrew McKellips (advisor: S. Verdú), July '98.
21. Richard Bang (advisor: S.C. Schwartz), Sept. '98.
22. R.S. Bichkar, Ph.D. student at IIT, Kharagpur, India, April '99.
23. Rajesh Sundaresan (advisor: S. Verdú), Aug. '99.
24. Jan Bajcsy (advisor: H. Kobayashi), Oct. '99.
25. Min Wu (advisor: B. Liu), April '01.
26. Pradeepa Yahampath, a Ph.D. student at Univ. of Manitoba, Aug. '01.

27. Arun Marar, ORFE student (advisor: W. Powell), Jan. '02.
28. Yingwei Yao (advisor: H.V. Poor), Aug. '02.
29. Shalinee Kishore (advisor: H.V. Poor and S.C. Schwartz), Oct. '02.
30. Wenmiao Lu, M.S. student at Nanyang Technological University, Singapore, Dec. '02.
31. Sudharman Jayaweera (advisor: H.V. Poor), Dec. '02.
32. Ying Zhu (advisor: S.C. Schwartz), Mar. '03.
33. Uri Erez, Ph.D. student at Tel-Aviv University, May '03.
34. Vitali Zagorodnov (advisor: P.J. Ramadge), Aug. '03.

UNDERGRADUATE ACADEMIC ADVISING

- Academic Advisor for Class of 1995 from Spring '92 to Spring '95.
- Freshman Advisor, September, 1996 (Class of 2000).
- Freshman Advisor, September, 1997 (Class of 2001).
- Academic Advisor for Class of 2002, from Spring '99 to Spring '02.
- Freshman Advisor, September, 2002 (Class of 2006).
- Academic Advisor for two students in Class of 2003, from Spring '00 to Spring '03.

UNDERGRADUATE RESEARCH ADVISEES

I have been actively involved in supervising undergraduates in independent projects. I have typically supervised or co-supervised about three to eight students each semester, for a total of over 80 semester-projects since Fall '91. Furthermore, several of these have resulted in conference publications, the results of one have formed part of a journal paper, and three of these have won the Calvin-Dodd MacCracken Award for best senior thesis in Engineering and Applied Science (May '93, May '96, May '03).

Fall '91:	Stephen Lin, Co-advisor (with Bede Liu) for Nelson Chang, Tom Chang, Marc Erickson, Susan Kim, Brian Loomis
Spring '92:	Nelson Chang, Stewart Taylor, Judy Pillay Co-advisor (with Bede Liu) for Lee An, Chris Guarriello, Michael Marucheck, Edward Niu, Wael Sinno, Lirenn Tsai
Fall '92:	Daniel Dodd, John Paz Co-advisor (with Bede Liu) for Warren Chain, Keith Frazier, Jesse Lerman, Wael Sinno, Ravi Srinivasan, David Sullivan, Jason Wang
Spring '93:	Jessie Lerman, Co-advisor (with Wayne Wolf) for Daniel Dodd, Co-advisor (with Bede Liu) for Ravi Srinivasan
Summer '93:	Research supervisor for Samuel Rosa of Staten Island College as part of Princeton University Title IX Program.
Fall '93:	Jesse Lerman, Co-advisor (with Peter Ramadge) for Rozaimi Ghani, Greg Moyer, Deepti Panchawagh
Spring '94:	Jessie Lerman, Co-advisor (with Peter Ramadge) for Thomas Watson, Chad Peterman, Rozaimi Ghani, Paul Riskind
Fall '94:	Co-advisor (with Peter Ramadge) for Thomas Watson,

	M. Shawn Mendelovich, Prisdha Dharma, Martin Sawicki
Spring '95:	Co-advisor (with Peter Ramadge) for Thomas Watson, M. Shawn Mendelovich, Martin Sawicki Co-advisor (with A. Wolfe) Andrew Wen, Peter Kovac, Davyd Ramirez
Fall '95:	Co-advisor (with Peter Ramadge) for Adam Mersereau, Drew Sauer, Sameet Mehta, Raj De Datta, Sanjeev Ramabhadran, Glenn Kashan
Spring '96:	Adam Mersereau Co-advisor (with P. Ramadge) for Drew Sauer, Glenn Kashan
Fall '96:	Co-advisor (with P. Ramadge) for Sal Desiano, Swati Dutta-Roy, Mike Madden, Jessica Eden Miller
Spring '97:	Adam Mersereau Co-advisor (with P. Ramadge) for Sal Desiano
Summer '97:	Co-advisor (with P. Ramadge, S. Schwartz as part of Princeton Summer Institute) for Hubie Chen (Stanford University), Kevin Chou (Cooper Union)
Fall '99:	Co-advisor (with P. Ramadge) for Michael Lindahl, Co-advisor (with W. Wolf) for George Nyako
Spring '00:	Dave Kulansky, Josh Model.
Fall '01:	Co-advisor (with H.V. Poor) for Andrew Lookingbill, Sean McCormick, Andrew Morabito, Eric Carty-Fickes, Christian Garcia
Spring '02:	Co-advisor (with H.V. Poor) for Adam Yoxtheimer, Dan Usas
Fall '02:	David Bradley, Co-advisor (with P. Bogucki) for Brett Antonides, Co-advisor (with R. Stengel) for David Lieb, Mark Siano, Co-advisor (with H.V. Poor) for Ali Kamaliddin (exchange student from Oxford)
Spring '03:	David Bradley, Co-advisor (with P. Bogucki) for Brett Antonides, Co-advisor (with H.V. Poor) for Ali Kamaliddin (exchange student from Oxford)

SERVICE AND PROFESSIONAL ACTIVITIES

DEPARTMENTAL SERVICE

- ISS Seminars (Spring 1992 to Fall 1994)
- Undergraduate Advisor for ISS Class of 1995 (Spring '92 to Spring '95)
- Coordinated CSP General Exam for Fall 1992
- Undergraduate Education Committee (Fall '92 to Fall '95)
- Computer Policy Committee (Spring '93 to Spring '95)
- Chair of Undergraduate Education Committee (Spring 1996 to Fall 1997)
- Freshman Advisor, September, 1996 (Class of 2000).
- Coordinated CSP General Exam for Spring 1997
- Freshman Advisor, September, 1997 (Class of 2001).
- Academic advisor for Class of 2002, from Spring 1999 to present.
- ABET retreat with SEAS, Spring 1999.
- Departmental ABET coordinator (with B. Dickinson), 1999-present
- Undergraduate Curriculum Committee, 2000 - 2002
- Undergraduate Laboratory Committee, 2000 - 2002
- Space and Infrastructure Committee, 2002
- Undergraduate Program Comittee, 2002 to present
- IEEE Faculty Representative, 2002 to present

SEAS AND UNIVERSITY SERVICE

- Search Committee for Assistant Dean of Multicultural Affairs, Spring 1993
- Cognitive Science Program Committee, Fall 1992 to present
- Robotics and Intelligent Systems Program Committee, Spring 1993 to present
- Transportation Systems Program Committee, Fall 1993 to present
- Faculty Fellow at Forbes College, Fall 1992 to present
- Committee on Undergraduate Life, 1998 - 1999
- Invited Seminar, for Engineering Council, Princeton, NJ "Introduction to LaTeX", Dec. 5, 2001.
- Invited Discussion Leader, English Language Program, Princeton University, March 11, 2002.
- SEAS ABET Committee, 2002 to present
- Committee on Discipline, Fall 2002 to present
- Faculty Fellow, Charter Club, 2002 to present
- Associate Dean for Academic Affairs, July 1, 2003 to present.
- SEAS Strategic Planning Committee, April 2003 to present.
- Chair, Ad-Hoc Committee on SEAS Computing Requirement, May 2003 to present.
- Co-chair (with K. Vanderlick), SEAS MEng Program, July 1, 2003 to present.

PROFESSIONAL LEADERSHIP, SERVICE, AND OTHER ACTIVITIES

Advisory Council

- **Engineering Advisory Council** for School of Engineering, Clarkson University, August 2003 to present.

Editorial Boards

- **BBS Associate** for the journal Brain and Behavioral Sciences (Spring '92 to present)
- **Associate Editor** for *IEEE Transactions on Information Theory*, 1999.
- **Editorial Board** for new journal *Foundations and Trends in Communications and Information Theory*, June 2003 to present.

Consulting and Visiting Positions

- **Expert Witness**, Omniplanar Inc. in case of UPS vs. Omniplanar Inc. involving machine-readable labels. Spent approximately two weeks preparing expert witness report during May and June, 1992 Spent approximately two weeks for depositions during May through August, 1993.
- **Visiting Research Fellow**, Australian National University, January 1996.
- **Technical Consultant**, Susquehanna International Group, 1997-2001. Regular consultant involving quantitative research, statistical arbitrage, and analysis of firm-wide stock trading.
- **Visiting Researcher**, Flarion Technologies, Inc., Summer 2001. Investigated downlink packet scheduling with quality-of-service requirements and throughput of wireless networks.

Conference and Workshop Organizer

- **Co-organizer** (with M. Orchard) for 30th Conference on Information Sciences and Systems (CISS '96), March 1996.
- **Co-organizer** (with M. Chiang) for 38th Conference on Information Sciences and Systems (CISS '04), March 2004.
- **Co-organizer** (with K. Vanderlick) for 11 SEAS Strategic Planning Workshops, Princeton University. Fall 2003.

Conference/Workshop Program Committees, Session Chair, etc.

- **Session Chair**, Princeton CISS, March 1992.
- **Program Committee**, IEEE Regional Controls Conference, June, 1994.
- **Publications Chair**, ISIT 1998.
- **Program Committee**, Symposium on Advances in System Theory, Oct., 1999.
- **Session Chair**, Financial Engineering and Insurance Workshop, Princeton University, November 1999.
- **Program Committee**, ISIT 2000.
- **Session Chair**, Princeton CISS, March 2000.
- **Session Chair**, Princeton CISS, March 2002.
- **Program Committee**, ISIT 2002.
- **Program Committee**, ISIT 2004.

Invited Workshops/Panelists (research trends), Panel Reviews

- **Invited Panelist**, IROS '92 (International Conference on Intelligent Robots and Systems, Raleigh, NC). Panel discussion on "Major Issues/Directions for Machine Learning," for a Workshop on *Dynamic World Autonomous Systems*, July 7-10, 1992.
- **Invited Participant**, ARO Workshop on Machine Intelligence, Feb. 1993.
- **Invited Panelist**, NSF Review Panel for Research Initiation Awards, April 1993.
- **Invited Panelist**, NSF Review Panel for CAREERS Awards, Jan. 1995.
- **Invited Participant**, NSF Workshop on Learning and Adaptation in Natural and Artificial Systems, Washington, D.C., Nov. 13-14, 1995.
- **Invited Panelist**, "The Business of Research", Fourth Annual LIDS Student Conference, MIT, Cambridge, MA, Jan. 28-29, 1999.
- **Invited Panelist**, NSF Review Panel for Learning and Intelligent Systems, Jan., 1999.
- **Invited Panelist**, Workshop on Communications and Network Technology for Distributed Robotics, Draper Labs, Cambridge, MA, May 21, 2002.
- **Invited Panelist**, Wireless Communications and Networking Conference, "The Business and Technical Case for Sensor Networks", New Orleans, March 17-20, 2003.
- **Invited Panelist**, NSF Review Panel for Information Technology Research, April, 2003.

Invited Book Reviewer

- **Invited Reviewer**, book draft *Discrete Stochastic Processes* by R. Gallager for Kluwer Academic Publishers, May, 1994.
- **Invited Reviewer**, book draft *Learning and Neural Networks* by M. Vidyasagar for Springer-Verlag, Sept., 1995.
- **Invited Reviewer**, book draft *Structure and Interpretation of Signals and Systems* by E. Lee and P. Varaiya for Academic Press, 2000.
- **Invited Reviewer**, book proposal *Learning, Adaptation, and Decision Making with Finite Data* by V. Saligrama, M. Dahleh, S.K. Mitter for Princeton University Press, 2001.

Paper and Grant Reviews

- Ongoing service as reviewer for U.S. Army Research Office, NSF, Hong Kong Research Grants Council, Israel Science Foundation, NSERC (Canada).
- Ongoing service as reviewer for a number of journals and conferences.

Miscellaneous

- **IT Society Liaison** to the IEEE Press, 1998-2000.
- **Princeton University Liaison** for IEEE Central Jersey Chapter, 2002 to present.

SEMINARS, PRESENTATIONS, WORKSHOPS, CONFERENCES

1. Invited Participant, Workshop on Learning and Geometry, sponsored by Systems Research Center, Univ. of Maryland, Airlie, VA, January, 1991.

2. Seminar, "Extensions of PAC Learning for Applications to Signal Processing and Geometric Reconstruction," M.I.T., May, 1991.

3. Presentation at CISS'92, Princeton University, "A Paradigm For Class Identification Problems," March 19, 1992.

4. Presentation at IBM, Thomas J. Watson Research Center, Hawthorne, NY, "Proposal to Study Theoretical Foundations of Handwriting Production and Recognition," March 27, 1992.

5. Invited Seminar for Cognitive Science Seminar Series, Princeton Univ., "Formal Models of Machine Learning," April 20, 1992.

6. Presentation for NTT Visit, Princeton Univ., "Formal Models for Machine Learning," April 29, 1992.

7. Presentation Corporate Affiliates Program, Princeton University, "Formal Models for Machine Learning," May 5, 1992.

8. Attendee at NEC Workshop on Computational Learning and Cognition, May 27-28, 1992.

9. Invited panelist/presentation at IROS '92 (International Conference on Intelligent Robots and Systems, Raleigh, NC), As part of a panel discussion for a Workshop on *Dynamic World Autonomous Systems*, "Major Issues/Directions for Machine Learning," July 7-10, 1992.

10. Presentation at COLT'92, University of Pittsburgh, "Learning With Generalized Examples and an Application to Stochastic Geometry," July 27-29, 1992.

11. Presentation for NSF Infrastructure Site Visit, Princeton Univ., "Some Ongoing Work/ Directions in Image Understanding and Machine Learning," July 31, 1992.

12. Invited Seminar, Siemens Corporate Research, Princeton, NJ., "Tomographic and Convex Set Reconstruction Techniques Applied to Laser Radar Data," August 6, 1992.

13. Invited participant for Workshop on Machine Intelligence sponsored by ARO, University of Pennsylvania, Feb. 9-10, 1993.

14. Presentation as part of Final Workshop for Electronic Eye Study, Cologne, Germany, "Research Issues in Learning and Adaptation for an Electronic Eye," March 16-17, 1993.

15. Invited presentation, CISS'93, Johns Hopkins Univ., "Applications of PAC Learning to Problems in Geometric Reconstruction," March 24, 1993.

16. Presentation for meeting of Institute for Transportation Engineers as part of presentation of ongoing work at Princeton on Intelligent Transportation Systems, "Image Processing/Computer Vision and Learning/Adaptation in Intelligent Transportation Systems," April 1, 1993.

17. Presentation of ongoing work at Princeton on Intelligent Transportation Systems for Dr. Ray Brandinger, Executive Director of the New Jersey Commission on Science and Technology. "Image Processing/Computer Vision and Learning/Adaptation in Intelligent Transportation Systems," April 14, 1993.

18. Invited Seminar and relations/recruiting at the Dept. of Electrical and Computer Engineering, University of Puerto Rico, Mayaguez. "Some Recent Work in Image Processing at Princeton University," May 13, 1993.

19. Presentation (with Bede Liu, Hisashi Kobayashi) of some work in image processing (video coding, chain coding) and ATM networks for Werner Wedham, et al. from Sharp Corporation, June 2, 1993.

20. Presentation at IVHS Day at Siemens Corporate Research. Participants from Siemens Corporate Research, Siemens Automotive, and Princeton University. "Image Processing/Computer Vision and Learning/Adaptation in Intelligent Transportation Systems," June 8, 1993.

21. Presentation at Annual Workshop on Computational Learning Theory, Santa Cruz, CA. "On Probably Correct Classification of Concepts," July 26, 1993.

22. Presentation at Annual Workshop on Computational Learning Theory, Santa Cruz, CA. "On-line Learning of Functions of Bounded Variation Under Various Sampling Schemes," July 28, 1993.

23. Presentation at 31st Annual Allerton Conference on Communication, Control, and Computation, Univ. of Illinois, "On Bandit Problems With Side Observations and Learnability," Sept. 29, 1993.

24. Invited participant for NASA-ARO Workshop on Formal Models for Intelligent Control, M.I.T., Sept. 30 - Oct. 2, 1993.

25. Invited Seminar in Statistics Seminar Series, Princeton University, "Stochastic Approximation Under Arbitrary Disturbances," Nov. 17, 1993.

26. Presentation at 13th Conference on Foundations of Software Technology and Theoretical Computer Science, I.I.T. Bombay, India, "On Local Versus Non-local Computation of Length of Digitized Curves," Dec. 14, 1993.

27. Invited participant and presentation at the Silver Jubilee Workshop on Computing and Intelligent Systems, I.I.Sc. Bangalore, India, "Stochastic Approximation Under Arbitrary Disturbances," Dec. 21, 1993.

28. Presentation at Prospective Graduate Student Recruiting Weekend, Dept. of Electrical Engineering, Princeton University, March 25, 1994.

29. Invited Seminar, Department of Electrical Engineering, Technion, Haifa, Israel, "Nearest Neighbor Estimation Under Arbitrary Sampling," June 16, 1994.

30. Presentation at 1994 IEEE International Symposium on Information Theory, "Learning Decision Rules for Pattern Classification Under a Family of Probability Measures," June 27, 1994

31. Presentation at SIAM Annual Meeting, "Recovering Convergence Results for Stochastic Approximation from Persistently Disturbing Conditions," July 27, 1994.

32. Invited presentation at SPIE Conference on Neural and Stochastic Methods in Image and Signal Processing, "Variational Versus Markov Random Field Methods for Image Segmentation," July 28, 1994.

33. Invited Presentation to Freshman Engineers in Class of 1998 as part of Merck Colloquium Series, "Image Processing: A Booming Technology," November 6, 1994.

34. Presentation as part of Workshop for Electronic Eye Project, Siemens Corporate Research, Princeton, "Motion Detection and Tracking," November 28, 1994.

35. Presentation at 1995 IEEE Information Theory Workshop "Nonparametric Regression Estimation for Arbitrary Processes," Rydzyna, Poland, June 25-29, 1995.

36. Presentation at 1995 IEEE International Symposium on Information Theory, "Existence of Strongly Consistent Rules for Estimation and Classification," Whistler, Canada, Sept. 18-22, 1995.

37. Participant in Workshop on Control Using Logic-Based Switching, Block Island, RI, Sept. 30 - Oct. 1, 1995.

38. Presentation at 1995 Allerton Conference, "An Overview of Some Results on Nonparametric Estimation for Arbitrary Processes," Univ. of Illinois, Oct. 4-6, 1995.

39. Invited Participant in NSF Workshop on Learning and Adaptation in Natural and Artificial Systems, Washington, D.C., Nov. 13-14, 1995.

40. Invited Seminar, "Nearest Neighbor Estimation Under Arbitrary Sampling," Department of Mathematics, Center for Systems and Control, Rutgers University, New Brunswick, NJ, Oct. 13, 1995.

41. Participant in Workshop on Verification and Control of Hybrid Systems, Rutgers University, Oct. 22-25, 1995.

42. Presentation at 1995 IEEE Conference on Decision and Control, "Universal Prediction of Nonlinear Systems," New Orleans, LA, Dec. 13-15, 1995.

43. Presentation at 1995 IEEE Conference on Decision and Control, "Necessary and Sufficient Conditions for the Convergence of Stochastic Approximation Algorithms Under Arbitrary Disturbances," New Orleans, LA, Dec. 13-15, 1995.

44. Presentation at 1995 IEEE Conference on Decision and Control, "On the Memory Requirements of Convergent On-line Decision Rules," New Orleans, LA, Dec. 13-15, 1995.

45. Invited Seminar, "Nonparametric Regression Estimation Under for Arbitrary Processes and Universal Output Prediction," Department of Systems Engineering, Australian National University, Canberra, Australia, Jan. 18, 1996.

46. Invited Seminar, "Nonparametric Regression Estimation Under for Arbitrary Processes and Universal Output Prediction," Department of Electrical Engineering, Technical University of Budapest, Budapest, Hungary, Mar. 6, 1996.

47. Invited Seminar, "Nonparametric Regression Estimation Under for Arbitrary Processes and Universal Output Prediction," Department of Computer Science, Concordia University, Montreal, Canada, Mar. 13, 1996.

48. Invited Seminar, "Nonparametric Regression Estimation Under for Arbitrary Processes and Universal Output Prediction," Department of Electrical Engineering, McGill University, Montreal, Canada, Mar. 14, 1996.

49. Seminar, "Some New Techniques in Video Analysis and Manipulation," Department of Mathematics, State University of New York at Potsdam, Potsdam, NY, Mar. 15, 1996.

50. Invited Seminar, "Nonparametric Regression Estimation Under for Arbitrary Processes and Universal Output Prediction," Department of Electrical Engineering, University of Manitoba, Winnipeg, Canada, May 27, 1996.

51. Invited Seminar, "Some New Techniques in Video Analysis and Manipulation," Department of Electrical Engineering, Purdue University, West Lafayette, IN, May 28, 1996.

52. Seminar, "Nonparametric Regression Estimation Under for Arbitrary Processes and Universal Output Prediction," Department of Electrical Engineering, University of Illinois, Urbana-Champaign, IL, May 30, 1996.

53. Invited Seminar, "Some New Techniques in Video Analysis and Manipulation," Department of Electrical Engineering, University of Illinois, Urbana-Champaign, IL, May 31, 1996.

54. Invited Seminar, "Nonparametric Regression Estimation Under for Arbitrary Processes and Universal Output Prediction," Department of Electrical Engineering, University of Illinois, Urbana-Champaign, IL, Sept. 9, 1996.

55. Invited Seminar, "Nonparametric Regression Estimation Under for Arbitrary Processes and Universal Output Prediction," Laboratory for Information and Decision Systems, M.I.T., Cambridge, MA, Oct. 8, 1996.

56. Participant, Interim Progress Meeting, "Princeton Panorama Project," Intel Corporation, Chandler, AZ, Jan. 18, 1997.

57. Participant, Conference on Mathematical Finance, Institute for Advanced Study, Princeton, NJ, Sept. 26, 1997.

58. Invited Participant, Workshop on Learning, Intelligent, and Hybrid Systems, Bangalore, India, Jan. 4-8, 1998.

59. Participant, International Symposium on Information Theory, Cambridge, MA, Aug. 17-21, 1998.

60. Invited plenary speaker, Fourth Annual LIDS Student Conference, MIT, Cambridge, MA, Jan. 28-29, 1999.

61. Invited Panelist for discussion on "The Business of Research" Fourth Annual LIDS Student Conference, MIT, Cambridge, MA, Jan. 28-29, 1999.

62. Speaker, Corporate Affiliates Program, Dept. of Electrical Engineering, Princeton University, "Some Techniques in Video Analysis and Manipulation", May, 1999.

63. Invited Participant, Symposium on Advances in System Theory, Cambridge, MA, Oct. 15-16, 1999

64. Session chair and participant, Financial Engineering and Insurance Workshop, Princeton University, Nov., 1999.

65. Speaker and Participant, MURI technical planning meeting, MIT, Cambridge, MA, May, 2000.

66. Speaker and Participant, MURI Kickoff Meeting, Army Research Laboratory, Beltsville, MD, July, 2000.

67. Participant, TRAC Meeting, Fort Leavenworth, Kansas, Dec. 1, 2000.

68. Speaker and Participant, MURI technical planning meeting, MIT, Cambridge, MA, March, 2001.

69. Speaker and Participant, MURI Review Meeting, Army Research Laboratory, Beltsville, MD, June, 2001.

70. Seminar, Flarion Technologies, Bedminster, NJ "Downlink Packet Scheduling with QoS Requirements", Sept. 11, 2001.

71. Invited Seminar, sponsored by Engineering Council, Princeton, NJ "Introduction to LaTeX", Dec. 5, 2001.

72. Invited Discussion Leader, "Communicating With Your Head of Course," part of AI Concerns Over Lunch series, English Language Program, Princeton University, March 11, 2002.

73. Invited Seminar, "Throughput of Wireless Networks," Department of Electrical and Computer Engineering, Clarkson University, March 28, 2002.

74. Invited Panelist and Participant, Workshop on Communications and Network Technology for Distributed Robotics, Draper Labs, Cambridge, MA, May 21, 2002.

75. Speaker and Participant, MURI Review Meeting, Army Research Laboratory, Beltsville, MD, June 14, 2002.

76. Participant, Review meeting for Decision-Making Under Uncertainty MURI's, Berkeley/Stanford/Cornell and UCLA/UC Irvine/Illinois, Berkeley, CA, July 16-17, 2002.

77. Invited Seminar, "Throughput Scaling in Wireless and Heterogeneous Networks," Department of Electrical Engineering, Yale University, Feb. 26, 2003.

78. Invited Panelist, Speaker, and Participant, Wireless Communications and Networking Conference, "The Business and Technical Case for Sensor Networks", New Orleans, March 17-20, 2003.

79. Invited Seminar, "Universal Output Prediction for Nonlinear Systems," Department of Mathematics and Department of Electrical and Computer Engineering, Clarkson University, April 3, 2003.

80. Invited Seminar, "Throughput Scaling in Wireless and Heterogeneous Networks," Systems Research Center and Center for Satellite and Hybrid Communications Networks, University of Maryland, May 2, 2003.

81. Speaker, Corporate Affiliates Program, Dept. of Electrical Engineering, Princeton University, "Throughput Scaling in Wireless Networks", May 8, 2003.

82. Invited Seminar, "Throughput Scaling in Wireless and Heterogeneous Networks," Department of Electrical Engineering, University of Colorado, May 19, 2003.

83. Invited Seminar, "Throughput Scaling in Wireless and Heterogeneous Networks," Department of Electrical Engineering, Colorado State University, May 22, 2003.

84. Invited Speaker and Participant, Twelfth Yale Workshop on Adaptive and Learning Systems Yale University, May 28-30, 2003.

85. Speaker, "Distributed Learning, Adaptation, and Coordination in Sensor Networks", Draper Laboratory, IR&D Project Kick-off, July 25, 2003.

86. Invited Panelist, Academic Job Search Workshop, sponsored by McGraw Center for Teaching and Learning and Career Services, Princeton University, Sept. 15, 2003.

87. Invited Speaker, "Engineering at Princeton: Frontiers, Outreach, and Strategic Planning", Princeton University Class of 1940, Annual Dinner, Dec. 4, 2003.