

# Henry S. Baird

## *Curriculum Vitae*

### A. Biographical Information

<b>Work</b>	Computer Science & Engineering Dept Lehigh University Bethlehem, PA 18015-3084	Email: <a href="mailto:baird@cse.lehigh.edu">baird@cse.lehigh.edu</a> Telephone: +1 (610) 758-6671 FAX -4096 URL: <a href="http://www.cse.lehigh.edu/~baird">http://www.cse.lehigh.edu/~baird</a>
<b>Home</b>	1841 Millard Street Bethlehem, PA 18017-5115	Email: <a href="mailto:hb@henrybaird.com">hb@henrybaird.com</a> Telephone: +1 (650) 888-8573

### **Educational History**

*Princeton University* Princeton, NJ

Ph.D. in Electrical Engineering and Computer Science, June, 1984. Advisor: Ken Steiglitz.  
Thesis Title: “Model-based Image Matching using Location.” A theoretical result relevant to computer vision: an expected quadratic-time pruned-search algorithm for matching rigid 2D sets of point-features under affine transformations and bounded noise, applying the Soviet ellipsoid algorithm for linear programming.

*Rutgers University* New Brunswick, NJ

M.S. in Computer Science, June, 1976. Advisor: William Easton. Thesis Title: “Design of a Family of Algorithms for LSI Mask Artwork Analysis.” The earliest description of a sweep-line algorithm for line-intersection, now recognized as a fundamental technique in computational geometry and an essential engineering component in the computer-aided analysis of VLSI layout geometry.

*Harvard College* Cambridge, MA

B.A. in Mathematics (*cum laude* in general studies), June, 1966.

### **Employment History**

*Lehigh University*, Computer Science & Engineering Department Bethlehem, PA

[2004– ] *Professor*. Co-Director (w/ Prof. D. Lopresti) of the Lehigh Pattern Recognition Research Laboratory. Director, the Lehigh Document Analysis and Exploitation project.

*Palo Alto Research Center*, Information Systems & Technologies Lab Palo Alto, CA

[1998–2004] *Principal Scientist and Area Manager*. Investigations of algorithms and systems for document image understanding. Manager of Ph.D. researchers in the Statistical Pattern & Image Analysis area. Responsible for transfer of innovative technology to Xerox mobile document management products, scan-enabled networked services, and legacy-conversion service bureaus. Member of the NSF/DARPA/NASA-sponsored Digital Library Initiative II project in the Computer Science Division at the University of California, Berkeley.

*Bell Laboratories*, Multimedia Communications Research Lab, Lucent Technologies Murray Hill, NJ

[1996–1998] *Department Head*. Manager of a multidisciplinary team of 14 Ph.D. researchers investigating keyword- and phrase-searching and media-conversion in voice mail, FAX, E-mail, and handwritten messages, using pattern recognition, information retrieval, and image analysis methods.

*Bell Laboratories*, Computing Sciences Research Lab, AT&T (later, Lucent) Murray Hill, NJ

[1984–1996] *Member of Technical Staff*. Research in document image analysis algorithms and systems, including highly versatile multilingual page readers. Successful technology transfer to AT&T operational systems and Lucent products.

*David Sarnoff Research Center*, RCA Corporation Princeton, NJ

[1973–1984] *Member, Technical Staff*. R&D in industrial robot vision, real-time factory information systems, design verification of VLSI circuits, and CAD data bases. Successful technology transfer into RCA factories.

*Applied Data Research, Inc.* Princeton, NJ

[1970–1973] *Software Engineer*. Design, implementation, and installation of software for mini-computer real-time telephone traffic monitoring systems.

*U.S. Army*. Fort Campbell, KY & Long Binh Post, VIETNAM

[1968–1970] *Specialist 4 (highest grade)*. Drafted July 1968. Ft. Campbell: Basic training; American Spirit Honor Medal; training in Data Analysis. USARV Data Services Center, Long Binh Post, VietNam July 1969 – April 1970: Senior Data Analyst Specialist. Honorable discharge April 1970.

## **B. Publications and Creative Activities**

### **Books Authored (Monograph)**

1. H. S. Baird, *Model-based Image Matching using Location*, MIT Press: Cambridge, MA, 1985.

### **Books Edited**

1. H. S. Baird & D. P. Lopresti (Eds.), *Human Interactive Proofs*, Proceedings of the 2nd Int'l Workshop (HIP2005), Bethlehem, PA, Springer-Verlag: Berlin, Lecture Notes in Computer Science LNCS 3517, May 19-20, 2005.
2. H. S. Baird & V. Govindaraju (Eds.), *Document Image Analysis for Libraries*, IEEE Computer Society Press: Piscataway, NJ, January 2004.
3. H. Bunke, P. S. P. Wang, & H. S. Baird (Eds.), *Document Image Analysis*, World Scientific: Singapore, 1994.
4. H. S. Baird, H. Bunke, & K. Yamamoto (Eds.), *Structured Document Image Analysis*, Springer-Verlag: New York, 1992.

## Chapters in Books

(Book chapters reprinted from journal articles are not listed separately here.)

1. “The State of the Art of Document Image Degradation Modeling,” in B. B. Chaudhuri (Ed.), *Digital Document Processing*, Springer-Verlag: Guildford, Surrey, UK, 2007. [ISBN 978-1-84628-501-1]
2. “Complex Image Recognition and Web Security,” in M. Basu & T. K. Ho (Eds.), *Data Complexity in Pattern Recognition*, Springer-Verlag London Ltd, 2006. [ISBN-10 1-84628-171-7]
3. “Web Security and Document Image Analysis,” (w/ K. Popat) in A. Antonacopoulos & J. Hu (Eds.), *Web Document Analysis: Challenges and Opportunities*, World Scientific, Series in Machine Perception and Artificial Intelligence, Vol. 55, Fall 2003.
4. “Data Structures for Page Readers,” (w/ D. J. Ittner) in A. L. Spitz & A. Dengel (Eds.), *Document Analysis Systems*, World Scientific (Singapore), pp. 3–15, 1995.
5. “Programmable Contextual Analysis,” (w/ D. J. Ittner) in A. L. Spitz & A. Dengel (Eds.), *Document Analysis Systems*, World Scientific (Singapore), pp. 76–92, 1995.
6. “Document Image Defect Models,” in L. O’Gorman & R. Kasturi (Eds.), *Document Image Analysis*, IEEE Computer Society Press (Washington, DC), 1995.
7. “The Skew Angle of Printed Documents,” in L. O’Gorman & R. Kasturi (Eds.), *Document Image Analysis*, IEEE Computer Society Press (Washington, DC), 1995.
8. “Bounded–Error Preclassification Trees,” (w/ C. L. Mallows) in D. Dori & A. Bruckstein (Eds.), *Shape, Structure, and Pattern Recognition*, World Scientific (Singapore), pp. 343–349, 1995.
9. “Neural–Net Applications in Character Recognition and Document Analysis,” (w/ L.D. Jackel, M. Y. Battista, J. Ben, J. Bromley, C.J.C. Burges, E. Cosatto, J.S. Denker, H.P. Graf, H.P. Katseff, Y. LeCun, C.R. Nohl, E. Sackinger, J.H. Shamilian, T. Shoemaker, C.E. Stenard, I. Strom, R. Ting, T. Wood, & C.R. Zuraw) in *Neural-Net Applications in Telecommunications*, Kluwer Academic Publishers, 1995.
10. “A Critical Survey of Music Image Analysis,” (w/ D. Blostein) in H. S. Baird, H. Bunke, & K. Yamamoto (Eds.), *Structured Document Image Analysis*, Springer-Verlag (New York), 1992.
11. “Hardware Considerations for Neural–Net Character Recognition Systems,” (w/ L. D. Jackel, H. P. Graf, B. Boser, J. S. Denker, Y. Le Cun, D. Henderson, R. E. Howard, & O. Matan) in H. Burkhardt, Y. Neuvo, & J. C. Simon (Eds) *From Pixels to Features II: Parallelism in Image Processing*, pp. 215–228, Elsevier Science Publishers B. V. (North-Holland), 1991. (Expanded from a presentation at the 2nd ‘From Pixels to Features’ Workshop, Bonas, France, August 27 – September 1, 1990.)
12. “Global–to–Local Layout Analysis,” in R. Mohr, T. Pavlidis, & A. Sanfeliu (Eds.), *Structural Pattern Analysis*, World Scientific (Singapore), pp. 181–196, 1990. (Expanded from *Proc., IAPR Workshop on Syntactic and Structural Pattern Recognition*, Pont-a-Mousson, France 1988.)
13. “A VLSI Architecture for Binary Image Classification,” (w/ H. P. Graf, L. D. Jackel, & W. E. Hubbard) in J. C. Simon (Ed.), *From Pixels to Features*, Elsevier Science Publishers B. V. (North-Holland), pp. 275–286, 1989.

14. “Industrial Applications,” in H. Bunke & A. Sanfeliu (Eds), *Syntactic & Structural Pattern Recognition — Fundamentals and Applications*, World Scientific Publishing Co., 1988.
15. “Applications of Multi-dimensional Search to Structural Feature Identification,” in G. Ferrate, T. Pavlidis, A. Sanfeliu, & H. Bunke (Eds.), *Syntactic & Structural Pattern Recognition*, Springer-Verlag (Berlin), pp. 137–149, 1988.
16. “Precise Robotic Assembly using Vision in the Hand,” (w/ M. Lurie) in Alan Pugh (Ed.), *Robot Sensors, Vol. 1 — Vision*, Springer-Verlag (New York), pp. 85–94, 1986.
17. “An Artwork Design Verification System,” (w/ Y. E. Cho) in H. Fuchs (Ed.), *VLSI Technologies in Graphics*, IEEE Computer Society Press (Silver Spring, MD), pp. 132–138, July, 1983.

### Articles in Refereed Journals

1. “PessimPrint: A Reverse Turing Test,” (w/ A. L. Coates & R. J. Fateman) *Int’l. J. on Document Analysis & Recognition*, Vol. 5, pp. 158–163, 2003. (Expanded from *Proc., 6th IAPR Int’l Conf. on Document Analysis & Recognition* Seattle, WA, pp. 1154–1158, September 10–13, 2001.)
2. “A Statistical, Nonparametric Methodology for Document Degradation Model Validation,” (w/ T. Kanungo, R. M. Haralick, W. Stuezele, & D. Madigan) *IEEE Trans. on PAMI*, Vol. 22, No. 11, pp. 1209–1223, November, 2000. (Expanded from “Validation and Estimation of Document Degradation Models,” (w/ T. Kanungo & R. M. Haralick) *Proc., 4th UNLV Symposium on Document Analysis & Information Retrieval*, Las Vegas, NV, pp. 217–225, April 24–26, 1995.)
3. “Pattern Classification with Compact Distribution Maps,” (w/ T. K. Ho) *Computer Vision and Image Understanding* Vol. 70, No. 1, pp. 101–110, April, 1998. (Expanded from “Perfect Metrics,” (w/ T. K. Ho) *Proc., 2nd IAPR Int’l Conf. on Document Analysis & Recognition*, Tsukuba Science City, Japan, pp. 593–597, October 20–22, 1993.)
4. “Large-Scale Simulation Studies in Image Pattern Recognition,” (w/ T. K. Ho) *IEEE Trans. on PAMI*, Vol. 19, No. 10, pp. 1067–1079, October, 1997.
5. “The Evolution of a Problem,” (w/ C. L. Mallows) Special issue of *Statistica Sinica* in honor of H. Robbins, Vol. 7, No. 1, pp. 211–220, January, 1997. (Expanded from an unpublished talk at The Robbins Conference, Rutgers University, New Brunswick, NJ, 1995.)
6. “Background Structure in Document Images,” *Int’l J. of Pattern Recognition & Artificial Intelligence*, Vol. 8, No. 5, pp. 1013–1030, October, 1994. (Expanded from H. Bunke, P. S. P. Wang, & H. S. Baird (Eds.), *Document Image Analysis*, World Scientific, Singapore, pp. 17–34, 1994.) (A preliminary version appeared in *Advances in Structural & Syntactic Pattern Recognition*, World Scientific: Singapore, 1993, a book form of *Proc., IAPR Workshop on Structural and Syntactic Pattern Recognition*, Bern, Switzerland, August 26–28, 1992.)
7. “Recognition Technology Frontiers,” *Pattern Recognition Letters*, Vol. 14, No. 4, pp. 327–334, April, 1993. (Expanded from *Proc., 2nd IPTP Conf. on Postal Processing Systems, etc*, Japanese Ministry of Posts and Telecommunications, Tokyo, Japan, January 27–28, 1992.)
8. “Reading Handwritten Digits: A ZIP Code Recognition System,” (w/ O. Matan, J. Bromley, C. J. C. Burges, J. S. Denker, L. D. Jackel, Y. Le Cun, E. P. D. Pednault, W. D. Satterfield, C. E. Stenard, & T. J. Thompson) *IEEE Computer*, ‘project overview,’ Vol. 25, No. 7, pp. 59–63, July, 1992.

9. “Anatomy of a Versatile Page Reader,” *Proc. of the IEEE*, Special Issue on OCR, Vol. 80, No. 7, pp. 1059–1065, July, 1992. (Expanded from “Anatomy of a Page Reader,” *Proc., IAPR Int’l Workshop on Machine Vision Applications (MVA’90)*, Tokyo, Japan, November 28–30, 1990.)
10. “Reading Chess,” (w/ K. Thompson) *IEEE Trans. on PAMI*, Vol. 12, No. 6, pp. 552–559, June 1990. (Expanded from *Proc., IEEE Computer Society Workshop on Computer Vision*, Miami, FL, pp. 277–282, November 31 - December 2, 1987.) (Reprinted in R. Kasturi & R. C. Jain (Eds), *Computer Vision: Principles & Applications*, IEEE Computer Society Press, 1991.)
11. “On the Recognition of Printed Characters of any Font or Size,” (w/ S. Kahan & T. Pavlidis) *IEEE Trans. on PAMI*, Vol. 9, No. 2, pp. 274–288, March, 1987.
12. “Feature Identification for Hybrid Structural/Statistical Pattern Classification,” *Computer Vision, Graphics, & Image Processing*, Vol. 42, No. 3, pp. 318–333, June, 1988. (Expanded from *Proc., IEEE Computer Society Conf. on Computer Vision & Pattern Recognition*, Miami Beach, FL, June, 1986.)
13. “Quick Analysis of TV Factory Tests and Repairs — the DARTS system,” (w/ T. M. Stiller) *RCA Engineer*, 25-4, pp. 7–10, December 1979 / January 1980.
14. “Fast Algorithms for LSI Artwork Analysis,” *Journal of Design Automation & Fault-Tolerant Computing*, Vol. 2, No. 2, IEEE Computer Science Press, pp. 179–209, May, 1978. (Expanded from *Proc., 14th ACM/IEEE Design Automation Conf.*, New Orleans, LA, pp. 303–311, June, 1977.) (Presented by invitation at: *CAD78 — 3rd Int’l Conf. on Computers in Engineering*, Brighton, U.K., March, 1978.) (Reprinted in H. Fuchs (Ed.), *VLSI Technologies in Graphics*, IEEE Computer Society Press (Silver Spring, MD), pp. 157–165, July 1983.) (Reprinted in *25 Years of Electronic Design Automation — A Compendium of Papers from the Design Automation Conf.*, ACM, June, 1988.)

## Refereed Conference Papers

(Conference papers expanded and/or reprinted as journal articles, book chapters, etc are not listed separately here.)

1. “Incorporating A Rich Linguistic Model into Whole-Book Recognition,” (w/ P. Xiu), *Proc., IS&T/SPIE Document Recognition and Retrieval Conf. (DR&R XVII)*, San Jose, CA, [to appear] January 17-21, 2010
2. “Time and Space Optimization of Document Content Classifiers,” (w/ D. Yin, C. An), *Proc., IS&T/SPIE Document Recognition and Retrieval Conf. (DR&R XVII)*, San Jose, CA, [to appear] January 17-21, 2010.
3. “Document Content Extraction Using Automatically Discovered Features,” (w/ S-Y Wang, C. An), *Proc., IAPR Int’l Conf. on Document Analysis and Recognition (ICDAR2009)*, Barcelona, Spain, July 26-29, 2009.
4. “Scaling Up Whole-Book Recognition,” (w/ P. Xiu), *Proc., IAPR Int’l Conf. on Document Analysis and Recognition (ICDAR2009)*, Barcelona, Spain, July 26-29, 2009.
5. “The Safe Use of Synthetic Data in Classification,” (w/ J. Nonnemaker), *Proc., IS&T/SPIE Conf. on Document Recognition and Retrieval (DR&R 2009)*, San Jose, CA, January 28 - February 1, 2009.
6. “Feature Selection Focused within Error Clusters,” (w/ S-Y Wang), *Proc., IAPR 10th Int’l Conf. on Pattern Recognition (ICPR 2008)*, Tampa, Florida, December 8-11, 2008.

7. "Truthing for Pixel-Accurate Segmentation," (w/ M. Moll, C. An), *Proc., IAPR Int'l Workshop on Document Analysis Systems (DAS 2008)*, Nara, Japan, September 17-19, 2008.
8. "The Convergence of Iterated Classification," (w/ C. An), *Proc., IAPR Int'l Workshop on Document Analysis Systems (DAS 2008)*, Nara, Japan, September 17-19, 2008.
9. "Towards Whole-Book Recognition," (w/ P. Xiu), *Proc., IAPR Int'l Workshop on Document Analysis Systems (DAS 2008)*, Nara, Japan, September 17-19, 2008.
10. "Segmentation-Based Retrieval of Document Images from Diverse Collections," (w/ M. Moll), *Proc., IS&T/SPIE Document Recognition and Retrieval XIV Conf.*, San Jose, CA, January 28 - February 1, 2008.
11. "Whole-Book Recognition using Mutual-Entropy-Driven Model Adaptation," (w/ P. Xiu), *Proc., IS&T/SPIE Document Recognition and Retrieval XIV Conf.*, San Jose, CA, January 28 - February 1, 2008.
12. "Document Content Inventory & Retrieval," (w/ M. Moll), *Proc., IS&T/SPIE Document Recognition and Retrieval XV Conf.*, San Jose, CA, January 30-31, 2008.
13. "Whole-Book Recognition using Mutual-Entropy-Driven Model Adaptation," (w/ P. Xiu), *Proc., IS&T/SPIE Document Recognition and Retrieval XV Conf.*, San Jose, CA, January 30-31, 2008.
14. "Document Content Classification and Retrieval," (w/ M. Moll), *Proc., IAPR 9th Int'l Conf. on Document Analysis and Recognition*, Curitiba, Brazil, September 23-26, 2007.
15. "Iterated Document Content Classification," (w/ C. An & P. Xiu), *Proc., IAPR 9th Int'l Conf. on Document Analysis and Recognition*, Curitiba, Brazil, September 23-26, 2007.
16. "Document Image Content Inventories," (w/ M. A. Moll & C. An), *Proc., IS&T/SPIE Document Recognition and Retrieval XIV Conf.*, San Jose, CA, 28 January - 1 February, 2007.
17. "CAPTCHA Challenge Tradeoffs: Familiarity of Strings versus Degradation of Images," (w/ S-Y Wang), *Proc., IAPR Int'l Conf. on Pattern Recognition (ICPR'06)*, Hong Kong, August 20-24, 2006.
18. "DIAL 2004 Working Group Report on Acquisition Quality Control," (w/ E. H. Barney Smith, W. Barrett, F. Le Bourgeois, X. Lin, G. Nagy, & S. Simske), *Proc., Int'l Conf. on Document Image Analysis for Libraries (DIAL 2006)*, Lyon, France, April 27-28, 2006.
19. "Towards Versatile Document Analysis Systems," (w/ M. R. Casey) *Proc., 7th IAPR Document Analysis Workshop (DAS'06)*, Nelson, New Zealand, February 12-15, 2006.
20. "Versatile Document Content Extraction," (w/ M. A. Moll, J. Nonnemaker, M. R. Casey, D. L. Delorenzo) *Proc., SPIE/IS&T Document Recognition & Retrieval XIII Conf.*, San Jose, CA, January 18-19, 2006.
21. "Distinguishing Mathematics Notation from English Text using Computational Geometry," (w/ D. Drake) *Proc., IAPR 8th Int'l Conf. on Document Analysis and Recognition (ICDAR2005)*, Seoul, Korea, August 31 - September 1, 2005.
22. "ScatterType: a Legible but Hard-to-Segment CAPTCHA," (w/ M. Moll, S-Y Wang) *Proc., IAPR 8th Int'l Conf. on Document Analysis and Recognition (ICDAR2005)*, Seoul, Korea, August 31 - September 1, 2005.

23. "A Highly Legible CAPTCHA that Resists Segmentation Attack," (w/ M. Moll, S-Y Wang) in H. S. Baird & D. P. Lopresti (Eds.), *Human Interactive Proofs: Proceedings of the 2nd Int'l Workshop (HIP2005)*, Bethlehem, PA, Springer-Verlag: Berlin, Lecture Notes in Computer Science LNCS 3517, May 19–20, 2005.
24. "ScatterType: a Reading CAPTCHA Resistant to Segmentation Attack," (w/ T. Riopka) *Proc., IS&T/SPIE Document Recognition & Retrieval XII Conf.*, San Jose, CA, pp. 197–207, January 16–22, 2005.
25. "Implicit CAPTCHAs," (w/ J. Bentley) *Proc., IS&T/SPIE Document Recognition & Retrieval XII Conf.*, San Jose, CA, pp. 191–196, January 16–22, 2005.
26. "Robust Document Image Understanding Technologies," (w/ D. Lopresti, B. Davison, W. Pottenger) *Proc., 1st ACM Hardcopy Document Processing Workshop (HDP 2004)*, Washington, DC, pp. 9–14, November 12, 2004.
27. "Decoder Banks: Versatility, Automation, and High Accuracy without Supervised Training," (w/ P. Sarkar) *Proceedings, IAPR Int'l Conf. on Pattern Recognition*, Cambridge, U.K., August 23–26, 2004.
28. "Difficult & Urgent Open Problems in Document Image Analysis for Libraries," *Proc., 1st Int'l Workshop on Document Image Analysis for Libraries (DIAL2004)*, Palo Alto, CA, January 23–24, 2004.
29. "Protecting Websites with Reading-Based CAPTCHAs," (w/ M. Luk) *Proc., 2nd Int'l Workshop on Web Document Analysis (WDA2003)*, Edinburgh, Scotland, August 3, 2003.
30. "Training on Severely Degraded Text-Line Images," (w/ P. Sarkar, X. Zhang) *Proc., 7th IAPR Int'l Conf. on Document Analysis and Recognition (ICDAR2003)*, Edinburgh, Scotland, August 3-6, 2003.
31. "BaffleText: a Human Interactive Proof," (w/ M. Chew) *Proc., 10th IS&T/SPIE Document Recognition & Retrieval Conf. (DR&R2003)*, Santa Clara, CA, January 23–24, 2003.
32. "Paper-to-PDA," (w/ T. Breuel, W. Janssen, & K. Popat) *Proc., 16th IAPR Int'l Conf. on Pattern Recognition (ICPR2002)*, Quebec City, Canada, August 12–15, 2002.
33. "Triage of OCR Output Using 'Confidence' Scores," (w/ P. Sarkar & J. Henderson) *Proc., 9th IS&T/SPIE Document Recognition & Retrieval Conf.*, San Jose, CA, January 20–25, 2002.
34. "Document Image Quality: Making Fine Discriminations," *Proc., 5th IAPR Int'l Conf. on Document Analysis and Recognition*, Bangalore, India, pp. 459–462, September 20–22, 1999. (Expanded from "Distinguishing Image Degradations by Bootstrapping," an abstract presented at the 3rd IAPR Workshop on Document Analysis Systems, Nagano, Japan, November 4-6, 1998.)
35. "A Retargetable Table Reader," (w/ J. Shamilian & T. Wood) *Proc., 4th Int'l Conf. on Document Analysis and Recognition*, Ulm, Germany, Vol. 1, pp. 158–163, August 18–20, 1997.
36. "Next-Generation Multimedia Messaging," (w/ J. Hu & R. S. Kashi) *Proc., 1st IEEE/SPS Workshop on Multimedia Signal Processing*, Princeton, NJ, pp. 501–506, June 23–25, 1997.
37. "Language Identification in Complex, Unoriented, and Degraded Document Images," (w/ D.-S. Lee & C. Nohl) *Proc., 2nd IAPR 1996 Workshop on Document Analysis Systems*, Malvern, PA, October 14-16, 1996.

38. “Degraded Character Image Restoration,” (w/ J. D. Hobby) *Proc., 5th UNLV Symposium on Document Analysis & Information Retrieval*, Las Vegas, NV, pp. 233–245, April, 1996.
39. “Power Functions and Their Use in Selecting Distance Functions for Document Degradation Model Validation,” (w/ T. Kanungo & R. M. Haralick) *Proc., 3rd IAPR Int’l Conf. on Document Analysis & Recognition*, Montreal, Canada, Vol. 2, pp. 734–739, August 14–16, 1995.
40. “Evaluation of OCR Accuracy using Synthetic Data,” (w/ T. K. Ho) *Proc., 4th UNLV Symposium on Document Analysis & Information Retrieval*, Las Vegas, NV, April 24–26, 1995.
41. “High-Performance OCR Preclassification Trees,” (w/ C. L. Mallows) *Proc., IS&T/SPIE Conf. on Document Recognition II*, San Jose, CA, pp. 47–53, February 5–10, 1995.
42. “Document Degradation Models: Parameter Estimation and Model Validation,” (w/ T. Kanungo, R. M. Haralick, W. Stuezel, & D. Madigan) *Proc., Int’l Workshop on Machine Vision Applications*, Kawasaki, Japan, pp. 552–557, December 13–15, 1994.
43. “A Family of European Page Readers,” (w/ D. Gilbert & D. J. Ittner) *Proc., 12th IAPR Int’l Conf. on Pattern Recognition*, Jerusalem, Israel, Vol. 2, pp. 540–543, October 9–13, 1994.
44. “Estimating the Intrinsic Difficulty of a Recognition Problem,” (w/ T. K. Ho) *Proc., 12th IAPR Int’l Conf. on Pattern Recognition*, Jerusalem, Israel, Vol. 2, pp. 178–183, October 9–13, 1994.
45. “Asymptotic Accuracy of Two-Class Discrimination,” (w/ T. K. Ho) *Proc., 3rd UNLV Symposium on Document Analysis & Information Retrieval*, Las Vegas, NV, April 11–13, 1994.
46. “A Self-Correcting 100-Font Classifier,” (w/ G. Nagy) *Proc., IS&T/SPIE Symposium on Electronic Imaging: Science & Technology*, San Jose, CA, pp. , 106–115, February 6–10, 1994.
47. “Language-Free Layout Analysis,” (w/ D. J. Ittner) *Proc., 2nd IAPR Int’l Conf. on Document Analysis & Recognition*, Tsukuba Science City, Japan, pp. 336–340, October 20–22, 1993.
48. “A 100-Font Classifier,” (w/ R. Fossey) *Proc., 1st IAPR Int’l Conf. on Document Analysis & Recognition*, St.-Malo, France, September 30 — October 2, 1991.
49. “A Neural Network Approach to Handprint Character Recognition,” (w/ L. D. Jackel, C. E. Stenard, B. Boser, J. Bromley, C. J. C. Burges, J. S. Denker, H. P. Graf, D. Henderson, R. E. Howard, W. Hubbard, Y. LeCun, O. Matan, E. Pednault, W. Satterfield, E. Sackinger, & T. Thompson) *Digest of Papers, COMPCON Spring ’91*, San Francisco, CA, pp. 472–475, February 25 – March 1, 1991.
50. “A FAX Reader for the Blind,” (w/ A. E. Milewski) *Proc., 24th Annual Asilomar Conf. on Signals, Systems, & Computers*, Pacific Grove, CA, pp. 881–886, November 5–6, 1990.
51. “VLSI Implementation of Electronic Neural Networks: and Example in Character Recognition,” (w/ L. D. Jackel, B. Boser, H. P. Graf, J. S. Denker, Y. LeCun, D. Henderson, O. Matan, & R. Howard) *Proc., IEEE Int’l Conf. on Systems, Man, & Cybernetics*, Los Angeles, CA, November 4–7, 1990.
52. “Handwritten Zip Code Recognition with Multilayer Networks,” (w/ Y. Le Cun, O. Matan, B. Boser, J. S. Denker, D. Henderson, R. E. Howard, W. Hubbard, & L. D. Jackel) *Proc., 10th IAPR Int’l Conf. on Pattern Recognition*, Atlantic City, NJ, Vol. 2, pp. 35–40, June 17–21, 1990.
53. “Optical Character Recognition: a Technology Driver for Neural Networks,” (w/ R. E. Howard, B. Boser, J. S. Denker, H. P. Graf, D. Henderson, W. Hubbard, L. D. Jackel, & Y. Le Cun) *Proc., IEEE Int’l Symposium on Circuits & Systems*, Vol. 3, pp. 2433–2436, New Orleans, LA, May 1–3, 1990.

54. "Image Segmentation by Shape-Directed Covers," (w/ S. E. Jones & S. J. Fortune) *Proc., 10th IAPR Int'l Conf. on Pattern Recognition*, Atlantic City, NJ, Vol. 1, pp. 820–825, June 17–21, 1990.
55. "Constrained Neural Network for Unconstrained Handwritten Digit Recognition," (w/ Y. LeCun, B. Boser, J. S. Denker, D. Henderson, R. E. Howard, W. Hubbard, & L. D. Jackel) *Proc., Int'l Workshop on Frontiers in Handwriting Recognition*, Montreal, April 2–3, 1990.
56. "Performance Testing of Mixed-Font, Variable-Size Character Recognizers," (w/ S. Lam) *Proc., 5th Scandinavian Conf. on Image Analysis*, Stockholm, Sweden, Vol. 2, pp. 563–570, June 2–5, 1987.
57. "Components of an Omnifont Page Reader," (w/ S. Kahan & T. Pavlidis) *Proc., 8th IAPR Int'l Conf. on Pattern Recognition*, Paris, France, pp. 344–348, October 27–31, 1986.
58. "Coordination Software for Robotic Workcells," (w/ E. Wells & D. Britton) *Proc., IEEE Computer Society Int'l Conf. on Robotics*, Atlanta, GA, pp. 354–260, March 13–15, 1984.
59. "A Linear Programming Approach to Noisy Template Matching," (w/ K. Steiglitz) *Proc., IEEE Computer Society Conf. on Pattern Recognition & Image Processing*, Las Vegas, NV, pp. 50–57, June 14–17, 1982.
60. "Monitoring a Factory Test-and-Repair Loop," *Proc., IEEE/IECI Applications of Mini- and Microcomputers Conf.*, Philadelphia, PA, pp. 129–132, March 17–20, 1980.
61. "A Survey of Computer Aids for IC Mask Artwork Verification," *Proc., IEEE Int'l Symposium on Circuits & Systems*, Phoenix, AZ, pp. 441–445, April 25–27, 1975.
62. "Communications Traffic Monitoring," (w/ M. Cramer, E. Lengel, & G. Schnerr) *Proc., Minicomputer Trends and Applications Symposium*, National Bureau of Standards, Gaithersburg, MD, pp. 51–58, April 4, 1973.

### Invited Conference Papers

(Conference papers expanded into book chapters or journal articles not listed separately here.)

1. "Document Analysis Systems Architectures for Digital Libraries," (w/ D. Lopresti & V. Govindaraju), *Proc., IAPR Document Analysis Systems Workshop (DAS04)*, Florence, Italy, September 8–10, 2004.
2. "Digital Libraries and Document Image Analysis," *Proceedings, IS&T Archiving Conference*, San Antonio, TX, April 20–23, 2004.
3. "Digital Libraries and Document Image Analysis," *Proc., 7th IAPR Int'l Conf. on Document Analysis and Recognition*, Edinburgh, U.K., August 3–6, 2003 (the Invited Conference Keynote Paper/Address).
4. "State of the Art of Document Image Degradation Modeling," *Proc., 4th IAPR Workshop on Document Analysis Systems*, Rio de Janeiro, Brazil, December 10–13, 2000 (invited).
5. "Model-Directed Document Image Analysis," *Proc., DARPA Symposium on Document Image Understanding Technology*, Annapolis, MD, April 14–16, 1999 (invited).
6. "Calibration of Document Image Defect Models," *Proc., 2nd UNLV Symposium on Document Analysis & Information Retrieval*, Las Vegas, NV, pp. 1–16, April 26–28, 1993 (invited).

7. “Document Image Defect Models and Their Uses,” *Proc., 2nd IAPR Int’l Conf. on Document Analysis & Recognition*, Tsukuba Science City, Japan, pp. 62–67, October 20–22, 1993 (invited).

### **Guest Editing of Journal Special Issues**

1. “Performance Evaluation: Theory, Practice, and Impact,” (w/ T. Kanungo & R. Haralick) special issue of *Int’l Journal on Document Analysis and Recognition*, Vol. 4, No. 3, March 2002.
2. “Document Image Retrieval,” (w/ F. Chen) special issue of *Information Retrieval*, Vol. 2, Nos. 2/3, May 2000.
3. “Document Image Understanding and Retrieval,” (w/ J. Kanai) special issue of *Computer Vision and Image Understanding*, Vol. 70, No. 3, June 1998.

### **Patents**

1. U. S. Patent No. 6,052,483, *Methods and Apparatus for Image Classification using Distribution Maps*, issued April 18, 2000.
2. U. S. Patent No. 5,825,925, *Image Classifier Utilizing Class Distribution Maps for Character Recognition*, issued October 20, 1998.
3. U.S. Patent No. 5,796,410 *Generation and Use of Defective Images in Image Analysis*, issued August 18, 1998.
4. U. S. Patent No. 5,647,021, *Image Segmenting Apparatus and Methods*, issued July 8, 1997.
5. Canadian Patent No. 2,043,593, *Generation and Use of Defective Images in Image Analysis*, issued January 16, 1996.
6. U. S. Patent No. 5,430,808, *Image Segmenting Apparatus and Methods*, issued July 4, 1995.
7. U. S. Patent No. 5,001,766, *Apparatus And Method for Skew Control Of Document Images*, issued March 19, 1991.

Patent applications are pending for: neural nets for OCR; degraded character image restoration; table-reader systems; ‘trriage’ methods; and reflowable text-image methods and systems.

### **C. Honors and Awards**

- The Outstanding Contributions Award of the International Conference on Document Analysis and Recognition, “for playing a central role in the 1990’s renaissance of basic research in document image analysis and for countless technical and methodological contributions to OCR research” (2003).
- PARC Outstanding Performance award (w/ P. Sarkar), for technology transfer of ‘trriage’ research results into full production in a Xerox scanning service bureau (2002).
- Elected Fellow of the Institute for Electrical and Electronic Engineering (IEEE), “for leadership in document image analysis research” (1999).

- Elected Fellow of the International Association for Pattern Recognition (IAPR), “for contributions to document analysis and for service to the IAPR” (1996).
- ACM Distinguished Dissertation award, including publication of Ph.D. thesis by the MIT Press (1984).
- RCA Laboratories Outstanding Achievement award for real-time factory data analysis software (1979).
- Outstanding Paper Award, IEEE/ACM 14th Design Automation Conference (1977).
- RCA Laboratories Outstanding Achievement award for design verification aids for VLSI circuits (1976).
- National Merit Scholarship.

### **Recent Keynote Addresses**

- Keynote Lecture “Towards Highly Versatile Document Image Analysis,” 2nd Korea-Japan Joint Workshop on Pattern Recognition (KRPR’2007), Matsushima, Japan, October 25–26, 2007.
- Keynote Conference Address “Digital Libraries & Document Image Analysis,” 7th IAPR Int’l Conf. on Document Analysis & Recognition, Edinburgh, Scotland, August 4, 2003.
- Invited talk “Image Understanding and Web Security,” 1st IEEE Workshop on Document Image Analysis and Retrieval, Madison, WI, June 21, 2003.
- Keynote Address “Document Image Degradation Modeling,” 4th IAPR Int’l Workshop on Document Analysis Systems, Rio de Janeiro, Brazil, 2000.
- Plenary Talk “Document Image Analysis Research,” IEEE Int’l Conf. on Computer Vision and Pattern Recognition, Fort Collins, CO, 1999.
- Invited talk “Quantitative Evaluation Methodologies in Document Image Analysis,” IEEE Workshop on Empirical Evaluation Methods in Computer Vision, Santa Barbara, CA, 1998.

## **D. Research Funding & Government Related Activities**

### **National Science Foundation Activities**

[2004] Co-organizer (w/ Venu Govindaraju), 1st NSF Int’l Workshop on Document Image Analysis for Libraries (DIAL2004), Palo Alto, CA.

[2002] Invited to serve on the Committee of Visitors for the Division of Information and Intelligent Systems (IIS). Every three years, each NSF program is reviewed by such an outside panel to evaluate the program itself (rather than the proposals it receives).

[2002] Co-organizer (w/ Manuel Blum), 1st NSF Int’l Workshop on Human Interactive Proofs (HIP2002), Palo Alto, CA.

[1999– ] Investigator, NSF/DARPA/NASA-funded Digital Library Initiative — II project on ‘Reinventing Scholarly Information Dissemination and Use,’ in the Electrical Engineering and Computer Science Dept at U.C. Berkeley, at the invitation of Principal Investigators Profs. Robert Wilensky & David Forsyth.

## Grants & Funded Activities

- U.S. Congressional Appropriation, *Document Analysis and Exploitation*, 2008-present.
- DARPA Program Grant (w/ Univ. Maryland and BBN), *MADCAT*, Joseph Olive, Program Manager, 2007-present.
- DARPA Seedling Grant (w/ Univ. Maryland & BBN), *Document Image Understanding*, for Program Manager Joseph Olive, 2006.
- Avaya Laboratories Research, Joint Research Grant, with Dr. Jon L. Bentley, 2006.

Although I was only rarely expected to attract grants during my years of industrial employment, nevertheless I tried, and succeeded: I was PI on a \$1M DARPA grant, and have played key roles in several other large grants (details immediately below). I have a long track record of successful collaborations with business counterparts in transferring innovative technologies into products (details under Administrative Experience below): the associated skills are transferable to grant application and management. NOTE: All of the grants below were competitive.

[2003] Principal Investigator, \$1.8M ARDA Video Analysis and Content Extraction (VACE) R&D Program, “Geometric and Statistical Methods for Video Text Extraction and Object Detection,” proposal submitted May 23, 2003 (awards are pending).

[1990–1995] Principal Investigator, \$1.1M DARPA- & DOD-funded ACIPS Project at Bell Labs; the funding was obtained because of my research into multi-lingual page readers; the project enjoyed successful DOD field trials.

[1993–1995] Key technology partner, \$5M U. S. Postal Service grant to build a Bell Labs prototype postal address reader incorporating hardened versions of my page layout analysis tools.

[1994–1995] Senior technical advisor, Bell Labs R&D project, funded by Federal agencies, to identify scripts and languages in FAXed documents.

[1992– ] Invited participant in the 1st DARPA Document Understanding Workshop in 1992 (Palo Alto, CA), the follow-on DARPA-funded Document Image Understanding (DIMUND) workshop in 1993 (Harper’s Ferry, VA), and in every later DOD-funded Symposia on Document Image Understanding Technology (SDIUT) in 1997 (Annapolis, MD), 1999 (Annapolis, MD), 2001 (Columbia, MD), and 2003 (Greenbelt, MD).

## E. Editor/Editorial Review Board Membership for Scholarly Publications

### Journals

[2001– ] Founding Member, advisory board, *Electronic Letters on Computer Vision and Image Analysis (ELCVIA)*.

[1996– ] Founding Member, editorial board, *Int’l Journal on Document Analysis and Recognition (IJ DAR)*.

[1989– ] Associate Editor, *Pattern Recognition (PR)*.

[1993–2000] Area Editor, *Computer Vision and Image Understanding (CVIU)*.

[1989–1991] Associate Editor, *IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI)*.

Much refereeing over many years for several journals including PAMI, CVIU, IJ DAR, & PR.

## **G. Teaching & Advising**

### **Teaching University Courses**

[2004] Lehigh University, CSE Dept, undergraduate semester course “Discrete Structures,” co-taught in two parallel sections with Prof. Donald Hillman. Twenty-seven students in my section, most of them juniors and seniors. The twenty-four students who evaluated the course rated my overall teaching effectiveness at 4.67 (out of a maximum of 5.0); by comparison, that semester the mean rating for the CSE Dept was 3.67, and for the entire College of Engineering 4.23.

[2000] U.C. Berkeley, Computer Science Division, graduate-level semester course “Document Image Analysis,” co-taught with Prof. Richard Fateman. Eight students, most of them graduate students. The five students who filled out reviews rated my teaching effectiveness at 6.8 (out of a maximum of 7.0); by comparison, at that time the mean overall rating for UCB CS instructors in graduate courses was 5.7, with standard error 0.4 (September 2002 HKN student honor society reviews).

[1986] Princeton University, Electrical Engineering & Computer Science Department, undergraduate semester course “Data Structures.” About 60 students, mostly sophomores and juniors. The 52 students who filled out reviews ranked my teaching, in overall quality, clarity, and intellectual stimulation, significantly higher than the departmental average, and somewhat higher than for the university as a whole.

### **Teaching Non-University Courses**

[1994] “Document Analysis Systems,” (w/ L. O’Gorman) a one-day tutorial at the IAPR Int’l Conf. on Pattern Recognition, Jerusalem, Israel.

[1982–1986] “Robot Programming Languages,” 3-hour lecture as part of *Applied Robotics for Industry* course at the Center for Professional Advancement, East Brunswick, NJ, and at the AT&T Corporate Education Center, presented annually for five years.

### **Service on Dissertation Committees & External Readerships**

- Qin Zhang, Ph.D. candidate under J. Danskin, Computer Science Dept, Dartmouth College, 1996–1997.
- Tapas Kanungo, Ph.D. candidate under R. Haralick, Electrical Engineering Dept, Univ. Washington, 1995–1996.
- Tao Hong, Ph.D. candidate under J. Hull, Computer Science Dept, SUNY Buffalo, 1994–1995.

## Mentoring and Advising of Students

- Pingping Xiu, 2007-present, PhD Candidate, research topic *Whole-Book Recognition*; has formed PhD Committee; has interned at Google, Inc. (Mountain View).
- Chang An, 2006-present, PhD Candidate, research topic *Iterated Classification*; has formed PhD Committee.
- Sui-Yu Wang, 2005-2009, PhD Candidate, dissertation title *Feature Selection Focused on Error Clusters*; expected to graduate Decemer 2009.
- Jean Nonnemaker, 2005-2009, PhD Dissertation *The Safe Use of Synthetic Data in Classification*. Now employed at LTS, Lehigh University.
- Michael Moll, 2005-2008, PhD Dissertation *Document Image Content Extraction*. Now employed at CACI, Mashington, DC.
- Matthew R. Casey, 2006-7, MS Thesis, Lehigh University. Now employed at Google, Inc. (Mountain View).
- Mark Luk, U.C. Berkeley undergraduate, 2002/3: building a CAPTCHA test website.
- Monica Chew, PARC summer intern, U.C. Berkeley graduate student, 2002: conference paper accepted for publication.
- Allison Coates, UC Berkeley graduate student, 2000: conference paper published, then expanded into a journal article.
- Tapas Kanungo, AT&T Bell Labs summer intern, Univ. Washington Ph.D. candidate, 1994: two conference papers, one journal article published.
- Derrick Gilbert, AT&T Bell Labs summer intern, undergraduate junior, 1993: conference paper published.
- Susan Dorward, AT&T Bell Labs summer intern, undergraduate junior 1989 & Princeton Ph.D. candidate 1991: two conference papers, one journal article, & one patent.
- Deborah Wallace, AT&T Bell Labs summer intern, undergraduate junior, 1988.
- Susana Lam, AT& Bell Labs summer intern, undergraduate junior, 1986: conference paper.

## H. Service — Academic

### For Lehigh University

Chair, Faculty Diversity Task Force, 2006-2007. Member, University Diversity Leadership Committee (UDLC), 2006-7. Chair, UDLC Benchmarking Committee. Founder, Lehigh Univ. Faculty/Staff LGBTQA Affinity group, 2006. RCEAS Tenure Committee 2006-present. RCEAS Representative to Business & Economics Faculty (Academic year 2004-2005).

Presentations to CSE BS Candidates and their Families, May 2004.

## H. Service — Professional

### Societies

[2000–2002] Second Vice-President of the Executive Committee, Int'l Assoc. for Pattern Recognition. The IAPR is a 25-year-old international association embracing the pattern recognition, computer vision, and image processing fields, and consisting of 38 non-profit, scientific, and professional organizations each of which is national, multi-national, or international in scope, altogether representing about 7,500 individuals. The 2nd VP is elected by the Governing Board.

[c. 1980] Founding Member and Newsletter Editor, IEEE Computer Society Technical Committee on Robotics.

### Conference Organization

- Co-organizer (w/ D. Lopresti), 2nd Int'l Workshop on Human Interactive Proofs, Bethlehem, PA, May 18–20, 2005.
- Workshops Chair, 8th IAPR Int'l Conf. on Document Analysis and Recognition, Seoul, Korea, 2005.
- Co-organizer (w/ V. Govindaraju), 1st Int'l Workshop on Document Image Analysis for Libraries (DIAL2004), Palo Alto, CA, January 2004.
- Workshops Chair, 7th IAPR Int'l Conf. on Document Analysis and Recognition, Edinburgh, U.K., 2003.
- Co-organizer (w/ M. Blum), 1st NSF Int'l Workshop on Human Interactive Proofs, Palo Alto, CA, 2002.
- Executive Committee Member, 6th IAPR Int'l Conf. on Document Analysis and Recognition, Seattle, WA, 2001.
- Area Chair for 'Applications relating to vision and document understanding,' IEEE Computer Society Conf. on Computer Vision and Pattern Recognition, Fort Collins, CO, 1999.
- Co-organizer (w/ T. Kanungo), 1st IAPR Workshop on Multilingual OCR, Bangalore, India, 1999.
- Co-chair of Program Committee (w/ A. Dengel & Y. Nakano), 4th IAPR Int'l Conf. on Document Analysis and Recognition, Ulm, Germany, 1997.
- Symposium Chair, 5th UNLV Symposium on Document Analysis and Information Retrieval, Las Vegas, NV, 1996.
- Co-chair (w/ L. Vincent), 2nd IS&T/SPIE Document Recognition conference, San Jose, CA, 1995.
- Co-organizer (w/ L. O'Gorman), IAPR Workshop on Syntactic and Structural Pattern Recognition (SSPR), Murray Hill, NJ, 1990.

I played a central role in the initiation of these continuing conference and workshop series:

- Series of seven IAPR Int'l Confs on Document Analysis and Recognition (ICDAR 1991, 1993, ...). The success of my SSPR'90 workshop, which I designed to focus on 'document image analysis,' triggered the ICDAR series (the first ICDAR proposals were floated on the last day of my workshop).
- Series of six IAPR Workshops on Document Analysis Systems (DAS 1994,1996, ...). L. Spitz& I conceived this series as the successor to SSPR'90, then we agreed that he and A. Dengel would run the first one.
- Series of three IAPR Workshops on Document Layout and Interpretation (DLIA 1999, 2001, ...). M. Worring and I conceived this series, then I invited T. Breuel to run the first one with him.
- Series of two IAPR Workshops on Web Document Analysis (WDA 2001, 2003, ...). I was one of a small group who strongly encouraged J. Hu and A. Antonacopoulos to run the first one, then I assisted them with advice.

## Program Committees

I have served on twenty-eight program committees (for, *e.g.*, ICPR, ICDAR, CVPR, DAS, SSPR, SDAIR, DR&R, & WAIAT) , and as session chair, working-groups organizer, and referee for many events.

[2006] (PC Chair) Int'l Workshop on Document Image Analysis for Libraries, Lyon, France, May, 2006.

[2003,2000] IEEE Int'l Confs. on Computer Vision and Pattern Recognition.

[2008,2006,2004,2002,2000,1998,1996,1994] IAPR Workshops on Document Analysis Systems.

[2008,2006,2004,2002,1998,1994] IAPR Int'l Confs. on Pattern Recognition.

[2009,2007,2005,2001,1999,1997,1995,1993,1991] IAPR Int'l Confs. on Document Analysis and Recognition.

[2000,1994,1992,1990,1992] IAPR Workshops on Structural and Syntactic Pattern Recognition.

[1997] Workshop on Automatic Identification Advanced Technologies.

[1995,1994,1992] UNLV/ISIR Symposia on Document Analysis and Information Retrieval.

Refereeing and chairing sessions for many events over many years, too numerous to detail.

## Administrative Experience & Leadership

For eight years, as Department Head at Bell Labs and Area Manager at PARC, I exercised a broad range of responsibilities relevant to academic administration. My overriding objective was always to ensure my department's technical excellence, which at both Bell Labs and PARC was measured by originality and importance of research results, quality of refereed publications, breadth of intellectual influence within the international research community, number and strength of patents, and (not least) commercial impact, corporate funding, and government grants.

To this end, I devoted much of my attention to the career development of junior (but intellectually free and independent) Ph.D. researchers, represented the department as liaison to other organizations, and

attracted sustained external support in the form of business sponsors, technology partners, and (increasingly) government grants. In addition, I have managed budgets, carried out annual performance reviews, overseen hiring and promotion processes, contributed to policy development, and served on a wide variety of committees.

In mentoring junior colleagues (including many people not working directly under me) I have taken pains to stimulate improvement in publications, patents, professional activities, grantsmanship, and interdisciplinary collaborations.

PARC's Statistical Pattern & Image Analysis (SPIA) research area investigated novel algorithms and develops software prototypes for recognition, segmentation, compression, and other forms of analysis of the contents of documents. The technical skills represented among the area's Ph.D. researchers included computer vision, document image analysis, information theory and coding theory, pattern recognition, statistical modeling, computer-science data structures and algorithms, and Web engineering. Our research results were relevant to digital libraries, eBooks, mobile documents, web security, legacy-conversion scan-and-convert service bureaus, and paper-digital interfaces. I negotiated formal corporate (Xerox) funding support for this group in the amount of \$940,000 per year.

My personal research on reading-based CAPTCHAs has attracted widespread positive news coverage starting in 2002, in Scientific American, The New York Times, ABC News, Computerworld, PC magazine, etc.

As a Department Head at Bell Laboratories (BL), I assembled a multidisciplinary research team of 14 Ph.D. researchers investigating innovative algorithms and systems for the translation, recognition, and retrieval of multimedia documents. The technical fields represented in my department included computer vision, information retrieval, content-based image retrieval, pattern recognition, and speech recognition systems. Our most promising applications included keyword- and phrase-searching and media conversion in voice mail, FAX, E-mail, and handwritten messages.

## **Technology Transfer & Commercial Impact**

Results of my personal research have been incorporated in commercially released products:

1. VLSI design-rule checking algorithms (incorporated in several commercial software products).
2. Network-based FAX/OCR services (the 'ECS' service, AT&T BCS).
3. FAXed forms-reading software (the 'FIRST' product, Lucent IPD Software Solutions).
4. Table reader system (the 'TRS' product, Lucent IPD Software Solutions).
5. Digital library service (the 'RightPages' product, AT&T CCS & Lucent BL Library Services).
6. Courtesy-amount readers for printed and handwritten personal and business checks (AT&T GIS/NCR and Lucent IPD Software Solutions).

Innovative technology based on my research has been used on a large scale in 'in-house' applications.

1. VLSI design-rule checking algorithms, saving the RCA Solid State Division several million dollars in computing, redesign, and refabrication costs.
2. Factory data analysis software, used heavily in production in a RCA Color TV factory.
3. Telephone bill-reading, saving AT&T over \$1M/year.

As a manager, I have overseen the successful technology transfer of others' research.

1. T. K. Ho: 'distribution-map' classifiers, incorporated in the AT&T bill-reading application.
2. J. Li: high-performance glyph decoding, for the Xerox DataGlyph Toolkit product.
3. P. Sarkar: 'triage' quality control tools for legacy-conversion service bureaus, saving Xerox \$150k on a single contract.

## **Research & Teaching Interests**

My technical interests embrace document image analysis, image processing, computer vision, pattern recognition, digital libraries, human interactive proofs, design & analysis of algorithms, computational geometry, combinatorial optimization, and software engineering.

My principal research has been in the following areas:

1. *image understanding theory, algorithms, and systems*, especially high-performance computer vision systems, image degradation modeling (*e.g.* generation of synthetic training/testing data and vision-based human interactive proofs for Web security), versatile systems architectures (*e.g.* multilingual page and multiform table readers), and document-image segmentation (*e.g.* white-space layout analysis methods, global-to-local strategies);
2. *computer & robot vision*, especially asymptotically fast algorithms for matching patterns in scenes; and
3. *computer-aided VLSI design*, especially practically efficient computational geometry algorithms with broad applications to layout geometry analysis & design-rule checking.

One of my on-going personal research activities is the investigation of quantitative stochastic models of image degradation, their theory, validation, and calibration, and their use in characterizing the intrinsic difficulty (Bayes risk) of recognition problems, in constructing optimal classifiers and adaptive recognition systems, and in designing Turing-like tests to distinguish human from machine users over the Web. In recent years I have focused often on algorithms and systems architecture for versatile and adaptive image understanding systems, including printed-page readers that are easily retargetable to new applications, including non-English languages and non-Latin writing systems. One of my experiments at Bell Labs (w/ Ken Thompson) set a world record for recognition accuracy on extended passages of poorly printed text, achieved by exploiting the semantics of image content.

## Invited Unpublished Presentations

I have been invited to speak at: 2nd Korea-Japan Joint Workshop on Pattern Recognition, Matsushima, Japan; ACM Chapter of Princeton, NJ; AT&T Research; AT&T Bell Labs; Avaya Labs Research; CRIN/INRIA (Nancy); Carnegie-Mellon Univ.; Colorado School of Mines; Colorado State Univ.; Daimler-Benz Research; Dartmouth College; George Washington Univ.; Google Research (Mountain View); Hitachi Central Research Laboratory (Kokubinji); IBM Almaden Research Ctr; IBM T. J. Watson Research Ctr; Johns Hopkins Univ.; Lucent Bell Labs (Murray Hill, NJ); Korea Advanced Institute of Science & Technology (KAIST); Korea University; MailBlocks, Inc.; MIT; Michigan State University; Microsoft Research; Nasa Ames Research Center; NTT Laboratories; Purdue; Rensselaer (RPI); Ricoh California Research Center; San Francisco State Univ.; SRI International (Menlo Park); SUNY Buffalo; SUNY Stony Brook; San Francisco State Univ.; San Jose State Univ.; Toshiba R&D; Tsinghua Univ. (Beijing); Univ. of Cagliari, Cagliari, Italy; U.C. Berkeley; Univ. Indiana (Bloomington); Univ. Maryland (College Park); Univ. Massachusetts (Amherst); Univ. Nebraska (Lincoln); Univ. South Florida (Tampa); Univ. Washington (Seattle); and Xerox PARC.

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