Mitsubishi Electric Research Laboratories (MERL)

Annual Report

July 2008 through June 2009

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Welcome to Mitsubishi Electric Research Laboratories (MERL), the North American corporate R&D arm of Mitsubishi Electric Corporation. In this report, you will find descriptions of MERL and our projects.

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Mitsubishi Electric Research Laboratories

Mitsubishi Electric Research Laboratories (MERL) is the North American subsidiary of the corporate research and development organization of Mitsubishi Electric Corporation. MERL conducts application-motivated basic research and advanced development in communications, image/video processing, data analysis and mechatronics technology.

MERL's mission—our assignment from Mitsubishi Electric—is twofold.

- Generating new technology in areas of importance to Mitsubishi Electric.
- Significantly impacting Mitsubishi Electric's business: using our technical expertise in partnership with organizations in Mitsubishi Electric to produce new and improved products in Mitsubishi Electric's main areas of business.

MERL's vision—our goal for ourselves—is also twofold.

- To be one of the world's premiere research laboratories, significantly advancing the frontiers of technology and making lasting impacts on the world.
- To be the prime source of technology for Mitsubishi Electric in our areas of expertise.

MERL focuses on five principal technology sectors:

Digital Communications - featuring wired & wireless transmission technology & networking.
Multimedia – featuring speech interfaces and the encoding, decoding & analysis of video.
Data Analytics – featuring data analysis and equipment condition monitoring.
Imaging – featuring computer vision algorithms and the observation of people in images.
Mechatronics – featuring advanced control of electro-mechanical systems.

An Algorithms group supports all five sectors, developing fundamental algorithms.

MERL is small enough to be agile and flexible in the dynamic marketplace of ideas. However, we gain leverage from the size, reputation, and diversity of our strong global parent. We turn our technical achievements into business successes by partnering with Mitsubishi Electric's business units and with other labs in Mitsubishi Electric's global R&D network.

We are strongly involved in the R&D community and standards activities, maintaining long-standing cooperative relationships with a number of research universities including MIT, CMU, Georgia Tech, and Harvard. We encourage our staff to be involved in their professional communities via conferences, papers, and continuing professional development.

MERL's output ranges from papers and patents, through proof-of-concept hardware and software prototypes, to modules for industry-first products.

This annual report is a snapshot of MERL's web site. For additional and updated information please visit "http://www.merl.com".

Richard C. Waters
President, MERL

MERL Organization

MERL is organized as six groups centered on technology areas, which collaborate closely to achieve groundbreaking results. We use a relatively flat organization to enhance the opportunities for collaboration within MERL. The five members of the top management team work closely together, guiding all aspects of MERL's operation.

Richard C. (Dick) Waters *Ph.D., MIT, 1978*
President, Chief Executive Officer & Research Fellow

Dick Waters received his Ph.D. in artificial intelligence (AI). For the next 13 years he worked at the MIT AI Lab as a Research Scientist and co-principal investigator of the Programmer's Apprentice project. Dick was a founding member of MERL's Research Lab in 1991. As a MERL researcher, his work centered on multi-user interactive environments for work, learning, and play. For this work, he was made a MERL Research Fellow in 1996. In December 1999, he became CEO of MERL as a whole. In addition to his duties at MERL, Dick is currently a member of the board of directors of the Computing Research Association.

Masahiro Fujita *M.S., The University of Tokyo, 1983*
Executive Vice President, Chief Financial Officer & Chief Liaison Officer

Masahiro Fujita joined Mitsubishi Electric's Industrial Electronics & Systems Laboratory in 1983 where he developed motion control technologies for industrial robots and other equipment. He moved to the Factory Automation Business Unit's Nagoya works in 1999. He transferred to the Advanced Technology R&D Center in 2002 where he rose to Senior Manager of the Mechatronics Department, before coming to MERL in 2008.

Joseph Katz *Ph.D., California Institute of Technology, 1981*
Vice President & Director

After working at Caltech's Jet Propulsion Laboratory for a number of years, Joseph Katz went to Symbol Technologies, where as Senior VP of R&D he participated in, initiated, and led projects in a wide range of technologies, including barcode/RFID data capture, optics, imaging, signal processing, computing, networking, security, biometrics, and communications. He joined MERL's management in 2004.

Kent Wittenburg *Ph.D., University of Texas at Austin, 1986*
Vice President & Director

Kent Wittenburg performed research at the Microelectronics and Computer Technology Corporation (MCC), Bellcore, and Verizon/GTE laboratories. His research focused on Human-Computer Interaction (HCI) technologies and he managed groups in natural language interfaces and Internet technologies. He joined MERL in 2001 as the leader of speech and HCI research and was promoted to Director in 2002. He is a Senior member of the ACM.

Mitsubishi Electric

One of the world's largest companies, Mitsubishi Electric Corporation (Mitsubishi Electric) has $37 billion in annual sales, $1.4 billion in operating profits (in the very difficult year ending in March 2009) and more than 100,000 employees around the world.

Mitsubishi Electric is composed of a wide range of operations. The primary business units are listed below.

Mitsubishi Electric Corp.

- **Information Systems & Network Services**
  IT Systems, Information Security/Encryption Systems, Business Solutions
- **Public Utility Systems**
  Government Systems, Transportation Systems, Very Large Display Devices
- **Energy & Industrial Systems**
  Electrical Generators, Power Transmission and Distribution Equipment
- **Building Systems**
  Elevators, Escalators, Building Monitoring/Security/Management Systems
- **Electronic Systems**
  Satellites, Radar Systems, Antennas, Electronic Toll Collection Systems
- **Communication Systems**
  Wired & Wireless Communication/Broadcasting Equipment and Systems
- **Living Environment & Digital Media Equipment**
  Televisions, DVD Recorders, Air Conditioners, Solar Power Generation Systems
- **Factory Automation Systems**
  Programmable Logic Controllers, Inverters, Servo-motors, Processing Machines
- **Automotive Equipment**
  Automotive Electrical Equipment, Car Electronics/Multimedia, Car Mechatronics
- **Semiconductor & Device**
  Optical Devices, High-Frequency &High-Power Semiconductors

Together, these ten business units produce approximately most of Mitsubishi Electric's revenue. Due to the wide applicability of MERL's research, MERL works with them all.

It is worthy of note that there are over 30 major independent companies in the world that use the word "Mitsubishi" in their names. These companies include Mitsubishi UFJ Financial Group, Mitsubishi Corporation, Mitsubishi Heavy Industries, Mitsubishi Chemical Holdings and Mitsubishi Motors, all of which are also among the world's largest companies. They have shared roots in 19th century Japan; however, they have been separate for many years and Mitsubishi Electric has been separate from all of them since its founding in 1921.

Mitsubishi Electric's US Operations

A significant part of Mitsubishi Electric's sales are in North America and many of Mitsubishi Electric's business units have North American subsidiaries. The largest US operations are listed below.

Mitsubishi Digital Electronics America, Inc. (Los Angeles, Mexicali MX)
High Definition Projection Televisions, DVD Recorders

Mitsubishi Electric Automotive America, Inc. (Detroit, Mason OH)
Alternators, Ignition Coils, Automotive Electronics

Mitsubishi Electric United States, Inc. (Los Angeles & other cities)
Semiconductors, Air Conditioners, Elevators, Photovoltaic Panels

Mitsubishi Electric Power Products, Inc. (Pittsburgh)
Power Transmission Products

Mitsubishi Electric Automation, Inc. (Chicago)
Factory Automation Equipment

Mitsubishi Electric Corporate R&D

Mitsubishi Electric has a global R&D network comprising five laboratories. The chart below summarizes the primary activities of these labs. MERL collaborates with all of these labs.

Corporate R&D Headquarters (Tokyo)

- **Advanced Technology R&D Center** (Amagasaki& Nagaokakyo, in greater Osaka)
  Power Electronics, Electro-mechanical, Ecology, Energy, Materials, Devices, Systems and Imaging Technologies
- **Information Technology R&D Center** (Ofuna, in greater Tokyo)
  Information, Communications, Multimedia, Electro-Optic and Microwave Technologies
- **Industrial Design Center** (Ofuna, in greater Tokyo)
  Product, Interface and Concept Design
- **Mitsubishi Electric Research Laboratories, Inc.** (Boston)
  Communications, Multimedia, Data Analytics, Imaging and Mechatronics Technologies
- **Mitsubishi Electric R&D Centre Europe, B.V.** (Rennes, France &Guildford, England)
  Communications, Digital Video, Energy &Environment Technologies

Awards and Commendations

The high caliber of MERL's research and researchers is evident in a variety of ways. Two are highlighted below. The first is the members of our staff that are Fellows of technical societies. The second is best paper awards received from outside organizations. Listed below are awards for the period of this Annual Report.

Current Technical Society Fellows

Dr. Joseph Katz, Fellow Institute of Electrical and Electronic Engineers
Dr. Joseph Katz, Fellow Optical Society of America
Dr. Huifang Sun, Fellow Institute of Electrical and Electronic Engineers
Dr. Jin Zhang, Fellow Institute of Electrical and Electronic Engineers

Best Paper Awards

Nishiuma, N.; Goto, Y.; Kumazawa, H.; Komaya K.; Nikovski, D., "Travel Time Prediction using Singular Value Decomposition", Journal of the Society of Instrument and Control Engineers of Japan (SICE), Vol 42 Issue 7, July 2006. (Received the SICE best paper award for 2008.)

Maaref, A., "Applications of Random Matrix Theory to the Performance Analysis of Wireless MIMO Communication Systems", PhD thesis, National Institute for Scientific Research, Montreal Canada, 2008. (2008 ADESAQ Prize of Excellence for best PhD dissertation in natural sciences and engineering in the Canadian province of Quebec.)

Thejaswi, C.; Pun, M-O.; Zhang, J.; Poor, H.V., "Distributed Opportunistic Scheduling with Two-Level Channel Probing", IEEE Conference on Computer Communications (INFOCOM), April 2009 (Best paper award.)

Technical Staff

The most important assets of MERL are its people. The following pages present the capabilities and interests of MERL's technical staff members as of the end of the period of this report. Additional information about their work can be found in the publications list and the project descriptions in this report. Complete information can be found in people's individual web pages at "http://www.merl.com/people".

Amit Agrawal *Ph.D., University of Maryland, 2006*
Research Scientist

Prior to his graduate studies, Agrawal worked as a DSP engineer at Hughes Software Systems, India, for one year. His research interests are in computer vision, image processing and computational photography. Current projects include motion photography, flash photography, surface reconstruction from gradient fields, high dynamic range imaging, and image editing under variable illumination using gradient domain methods.

Ramesh Annavajjala *Ph.D., University of California at San Diego, 2006*
Member Technical Staff

Annavajjala jointed MERL in 2008. Prior to that, he was a Systems Research Engineer at ArrayComm LLC, in San Jose, CA., working for the development of advanced interference cancellation algorithms for next generation wireless standards.

Luigi (Lou) Baccari *B.S., University of Massachusetts of Lowell*
Manager Computational & Network Services

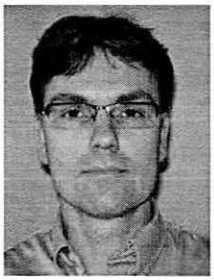
Baccari has 23 years of experience in the System and Network Administrations field. For the 6 years prior to joining MERL he worked at HP/Compaq's Cambridge Research Labs providing System and Network. Previous to that he worked for Force Computers, Lycos and Digital Equipment Corp. as Data Center Manger and in various System/Network Support roles.

John C. Barnwell III
Research Associate

John Barnwell is a former Software Engineer developing configuration and database systems for the aircraft manufacturing, food processing, large truck manufacturing, and computer manufacturing industries. His current personal interests include amateur radio, CNC control systems, and mechanical and electrical design.

Ghulam M. Bhatti *Ph.D., Boston University, 1998*
Principal Technical Staff

For his thesis, Bhatti specialized in distributed and parallel discrete event simulation. Before joining MERL in 2000, he worked as a Sr. Software Engineer at Evare LLC, Inc, developing software for a network switch and implementing an RSA cryptographic scheme. He also worked at Excel Tech. Ltd. (XLTEK) developing embedded software for a portable EEG device. Currently, he is working on Home Networking and Digital TV.



Scott A. Bortoff *Ph.D., University of Illinois Urbana Champaign, 1992*
Group Manager Mechatronics

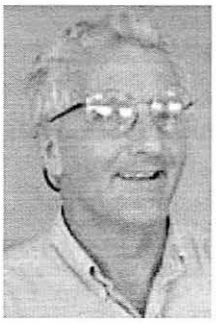
After receiving his Ph.D., Scott became a professor in the Electrical and Computer Engineering department at the university of Toronto. More recently Scott worked at the United Technology Research Center, where he founded the Control Technology group and then managed that group as well as the Control Systems group.

Petros T. Boufounos *Sc.D. ,Massachusetts Institute of Technology, 2006*
Member Technical Staff

Before joining MERL in 2009, he was with the Digital Signal Processing Group at Rice University doing research in the area of Compressive Sensing. In addition to compressive sensing, his immediate research interests include signal processing, data representations, frame theory, and machine learning applied to signal processing.

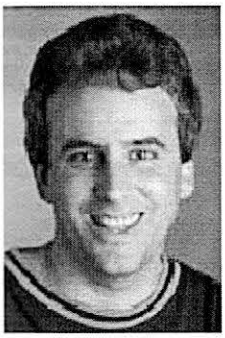
Matthew E. Brand *Ph.D., Northwestern University, 1994*
Distinguished Research Scientist

Brand studies unsupervised learning from sensory data. His results include spectral solutions for reconstructing manifolds from samples, decision-theoretic elevator group control, a linear-time online SVD, recovery of non-rigid 3D shape from ordinary video, and an entropy optimization framework for learning. He has received best paper awards in computer vision (CVPR2001) and scheduling (ICAPS2003).



Dirk Brinkman *J.D., Suffolk University Law School, 1990*
Patent Counsel

Brinkman's undergraduate and Masters work was in Medical Physics. Prior to joining MERL in 1998, he spent most of his career at Digital Equipment Corporation, first as an engineer and product manager in the Medical Systems Group and then as a Patent Attorney for Digital's Research Laboratories in Cambridge MA and Palo Alto CA.

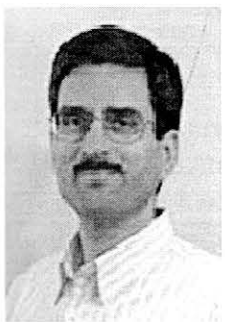


William J. Butera *Ph.D., Massachusetts Institute of Technology, 2002*
Senior Research Scientist

Previously at Intel, Bill initiated and drove a technology initiative on Scale-free Architecture. Prior to Intel, he worked at the MIT Media Lab's Center for Bits and Atoms, Micronas Semiconductor and Standard Elektrik Lorenz (both in Germany). Bill is working on various projects that have severe computational requirements (e.g., patient alignment for Particle Beam Therapy).

Christian M. Chilan *Ph.D., University Illinois Urbana Champaign, 2009*
Visiting Scientist

Christian's research interests include optimal control and numerical optimization. His graduate work focused on the optimization of spacecraft trajectories and missions. He also carried out research in the performance of parallel computing systems while working at The HDF Group.

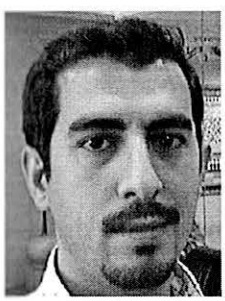


Robert A. Cohen *Ph.D., Rensselaer Polytechnic Institute, 2007*
Principal Technical Staff

Prior to getting his Ph.D., Robert Cohen worked for 11 years at Philips Research Labs in NY on HDTV, scalable video streaming, video surveillance, and rapid prototyping for VLSI video systems. His current research interests are algorithms and architectures for video coding and communications, and video, image and signal processing. He is currently researching video transcoding and next-generation video coding algorithms.

Chunjie Duan *Ph.D., University of Colorado at Boulder, 2008*
Principal Technical Staff

Prior to joining MERL, Duan worked for Alcatel, Qualcomm and Ericsson and other telecomm companies for over 10 years. His research interests are in wireless and optical communications, digital signal processing and VLSI/CAD technology. He is currently working on Ultra-Wideband system development and LSI implementation.



Huseyin Erdim *Ph.D., University of Connecticut Storrs, 2009*
Visiting Scientist

During his master studies, Huseyin worked on improving productivity in free-form surface machining based on the physics of the cutting process, for which he received an Outstanding Young Researcher Award from the Japan Society of Mechanical Engineers in 2005. His research interests include theoretical and computational tools for systematic mechanical design, manufacturing and analysis.

Alan W. Esenther *M.Sc., Boston University, 1993*
Principal Technical Staff

Esenther enjoys human-computer interaction (HCI) design, distributed software development, graphical user interfaces and Internet technologies. His recent work has focused on touch applications that support multiple concurrent users (think multiple mice), rapid image presentation for video browsing, and instant co-browsing (lightweight real-time distributed collaboration using unmodified web browsers).

Antonie (Tony) Ezzat *Ph.D., Massachusetts Institute of Technology, 2002*
Principal Technical Staff

Previously, Tony was a research scientist at the MIT Computer Science and Artificial Intelligence Lab and the McGovern Institute for Brain Research, where he worked on novel algorithms for speech processing based on spectro-temporal patches. Dr. Ezzat received his B.S., M.Eng., and PhD degrees from MIT under the direction of Professor Tomaso Poggio.

Clifton L. Forlines *Ph.D., University of Toronto, 2009*
Research Scientist

Forlines' research interests include the design and evaluation of novel user interfaces. His current research projects span from three-dimensional presentation of and navigation through recorded digital video, to collaborative tabletop user interfaces, to using hand-held projectors for augmented reality. He is currently leading the user evaluation of three projects, MediaFinder, TimeTunnel, and DiamondSpin.

Tyler W. Garaas *Ph.D., University of Massachusetts Boston, 2009*
Visiting Scientist

Tyler was a member of the visual attention laboratory at U. Mass. Tyler earned his bachelor's degree in computer science at Montana State University. His work at UMass Boston included human visual attention studies, neural modeling of primate visual systems, and robotics.

Abraham M. Goldsmith *M.S., Worcester Polytechnic Institute, 2008*
Research Associate

Abraham Goldsmith has five years industry experience as a design Electrical Engineer and holds a master in Electrical Engineering from Worcester Polytechnic Institute. He's also very good at mechanical design and is a "shop demon".

Evandro Gouvêa *Ph.D., Carnegie Mellon University, 1999*
Principal Technical Staff

Previously at CMU, Dr. Evandro Gouvea was involved in the design and development of Sphinx-4—a Java platform speech recognition system. He was also part of Project LISTEN, which uses speech recognition to help elementary school-aged children learn how to read. Prior to CMU, he worked at Vocollect, Inc., where he built the speech recognition system used in their core products wearable computer for warehouses.

Jianlin Guo *Ph.D., Windsor University, 1995*
Principal Technical Staff

Guo worked at Waterloo Maple for a year and a half as a software developer before joining MERL in 1998. He primary research interests include home networks, digital broadcasting, and wireless computing.

Bret A. Harsham *B.S., Massachusetts Institute of Technology*
Principal Technical Staff

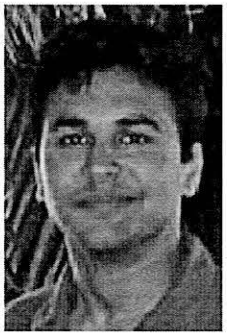
Harsham joined MERL in 2001 to pursue interests in speech interfaces and speech-centric devices. Previously, Bret spent 3 1/2 years at Dragon Systems designing and implementing handheld and automotive speech products. Earlier, he was a principal architect of a Firewall and Virtual Private Network product. Harsham's other technical interests include distributed architectures, knowledge representation, and language theory.

Frederick J. Igo, Jr. *B.A., LeMoyne College, 1982*
Senior Principal Technical Staff

Igo's professional interests are in software development and its process. He joined MERL in 1985 and has worked on various software technologies, including Distributed Computing, Distributed OLTP, Message Queuing, Mobile Agents, OLAP/MDDB and Data Mining. Prior to joining MERL Fred worked at IPL systems.

Yuri A. Ivanov *Ph.D., Massachusetts Institute of Technology, 2001*
Senior Principal Technical Staff

Ivanov's main research interests lie in the area of Computer Vision, Machine Learning and Data Mining. In particular, he is interested in dynamic observations - video sequences, sounds, gestures, actions and events.



Ankur Jain *Ph.D., University of California, Santa Barbara ,2006*
Member Technical Staff

Ankur Jain's doctoral thesis explores the aspects of efficient machine learning and data mining techniques for evolving data such as data streams. As a member of the Analytics team at MERL, his work has been focused on developing incremental machine learning techniques for sensor data analysis.

Elena J. Jakubiak *Ph.D., Tufts University, 2009*
Visiting Research Scientist

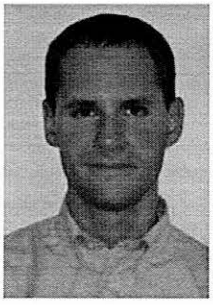
Elena first joined MERL as an intern in 2003 and subsequently as a visiting scientist in 2009. During the intervening period, she pursued her PhD in computer graphics, researching problems pertaining to high-quality text rendering in collaboration with MERL. Currently, Elena continues research on text representations and rendering.

Michael J. Jones *Ph.D., Massachusetts Institute of Technology, 1997*
Senior Principal Technical Staff

Jones joined MERL in 2001 after 4 years at the Digital/Compaq Cambridge Research Laboratory. His main area of interest is computer vision. He is particularly interested in using machine-learning approaches for solving computer vision problems. He has focused on algorithms for detecting and analyzing people in images and video such as face detection, skin detection and facial analysis using morph able models.

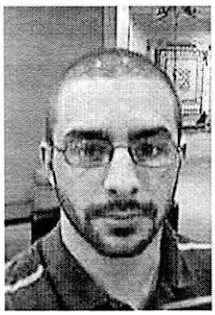
Keisuke Kojima *Ph.D., University of Tokyo, 1990*
Senior Research Scientist / Senior Liaison

Kojima spent 8 years in Melco's Central research lab and 9 years at AT&T Bell Labs. He has been involved in the research and development of semiconductor lasers, optical communication modules, and optical communication and sensor systems. At MERL, he is engaged in the research of security systems and sensor technologies.



Christopher Laughman *Ph.D., Massachusetts Institute Technology, 2008*
Member Technical Staff

Christopher received his Ph.D. in the Building Technology section of the department of Architecture at MIT. His current research includes the investigation of modeling and parameter identification problems for electrical, mechanical, and thermal systems as found in buildings and transportation systems.



Jonathan Leonard *B.S., Northeastern University, 2008*
Systems & Network Administrator

Jon works in the Central Services Department at MERL. He previously worked at MIT Lincoln Laboratory and graduated from Northeastern University. While not at work, he enjoys marital arts and regularly competes in competitions.

Amine Maaref *Ph.D., University of Quebec, 2007*
Visiting Research Scientist

Amine is helping us to develop a 3GPP LTE system simulator to perform system analysis for various schemes such as virtual MIMO, inter-cell interference management, beam forming and MIMO interference management. His expertise is in the area of very high configuration MIMO wireless systems. Before joining MERL, Amine was an NSERC postdoctoral research fellow with the University of British Columbia.

Tim K. Marks *Ph.D., University of California San Diego, 2006*
Research Scientist

Tim's research interests lie primarily in developing and applying statistical models for machine learning to problems in vision, both in order to solve problems in computer vision and in order to better understand human vision.

Janet McAndless
Technical Project Specialist

McAndless formerly held a variety of tech-related positions including management of peer review processes, web development, film and television post production, technical writing/documentation, and technical-support. For many years she has been involved with the planning of the annual SIGGRAPH conferences.

Barton E. Nicholls *Northeastern University*
System & Network Administrator

Nicholls is a member of MERL's Computer Network Services Group. He supports primarily UNIX and some Windows client and infrastructure software and hardware, and networking services for MERL. He comes to us from Verizon's Network Operations Management Group, and before that Information Technology at Art Technology Group.

Daniel N. Nikovski *Ph.D., Carnegie Mellon University, 2002*
Team Leader Data Analytics Group

Nikovski's research is focused on algorithms for reasoning, planning, and learning with probabilistic models. His current work is on the application of such algorithms to hard transportation problems such as group elevator control and traffic prediction. He also has varied interests in the field of data mining.

Philip V. Orlik *Ph.D., State University of New York at Stony Brook, 1999*
Team Leader Mobile Systems Group

Orlik joined MERL's digital communications and networking group in 2000. His research interests include wireless and optical communications, networking, queuing theory, and analytical modeling.

Ronald N. Perry *B.Sc., Bucknell University, 1981*
Distinguished Research Scientist

Prior to joining MERL in 1998, Perry was a consulting engineer at DEC developing a three-dimensional rendering ASIC called Neon. Ron has consulted for many companies including Kodak, Adobe, Quark, and Apple over the last 20 years, developing software and hardware products in the areas of computer graphics, imaging, color, and desktop publishing. Ron's research interests are centered on key algorithms in computer graphics.

Fatih M. Porikli *Ph.D., Polytechnic University, 2002*
Senior Principal Technical Staff

Porikli's research interests are in the areas of video processing, computer vision, aerial image processing, 3-D depth estimation, texture segmentation, robust optimization, network traffic management, multi-camera systems, data mining, and digital signal filtering. Before joining MERL in 2000, he worked for Hughes Research Labs, Malibu, CA (1999) and AT&T Research Labs, Holmdel, NJ (1997).

Man-On (Simon) Pun *Ph.D., University of Southern California, 2006*
Member Technical Staff

Before joining MERL in 2008, Simon was a post-doctoral research fellow at Princeton University, NJ and worked for Sony Corporation in Tokyo where he was engaged in developing DAB/DVB-T receivers. Simon received the best paper award from the IEEE International Conference on Communications (ICC) Beijing, China in 2008.

Srikumar Ramalingam *Ph.D., INRIA Alpes, 2007*
Research Scientist

During his Ph.D. Srikumar worked on multi-view geometry algorithms for omni-directional and non-central camera models. His doctoral thesis received the best thesis prize and an honorable mention for the annual AFRIF thesis prize from the French Association for Pattern Recognition.

Shantanu Rane *Ph.D., Stanford University, 2007*
Research Scientist

Shantanu Rane's Ph.D. thesis applied distributed source coding concepts to error-resilient video transmission. Shantanu's research interests are in the areas of image communication and information theory. At MERL, he is working on problems involving distributed compression of images and video.

Zafer Sahinoglu *Ph.D., New Jersey Institute of Technology, 2001*
Principal Research Scientist

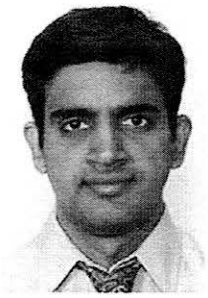
Sahinoglu worked at AT&T Shannon Labs in 1999, and joined MERL in March 2001. His research interests include home networking, QoS in video streaming and multicasting, wireless image sensor networks, traffic self-similarity and biomedical signal processing. He has made significant contributions to the emerging MPEG-21 and ZigBee standards.

Masashi Saito *Ph.D., Osaka University, 2006*
Senior Principal Technical Staff

Masashi Saito received his Ph.D. in Computer Science specializing in Distributed Systems. Before joining MERL in 2006, he worked as a Senior Software Engineer at MELCO's Information Technology R&D Center doing research on operating systems, Internet protocols and distributed systems. His interests include wireless networking, algorithms, software development and Internet services.

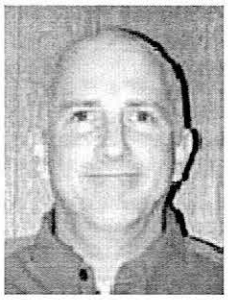
Bent K. Schmidt-Nielsen *B.S. Univ. of California at San Diego, 1971*
Team Leader Speech Group

Schmidt-Nielsen spent 7 years at Dragon Systems applying speech recognition to useful products. At MERL he is paying a lot of attention to making speech interfaces robust and usable. He has very broad interests in science and technology. Among many other activities he has taught genetics at the University of Massachusetts at Boston and he has been a leader in the development of an easy to use mass-market database.



Vijay Shilpiekandula *Ph.D. Candidate, Massachusetts Institute of Technology, 2009*
Research Scientist

Vijay received the 2008 R.V. Jones Memorial Scholarship from the American Society for Precision Engineering (ASPE) for his doctoral research on the design and control of flexure-based nano-positioning systems.



Alan Sullivan *Ph.D., University of California at Berkeley, 1993*
Senior Research Scientist

Prior to joining MERL, Alan Sullivan worked on developing and commercializing the DepthCube volumetric 3D display technology, (The DepthCube is a DLP-based rear- projection multiplanar display that produces physically deep 3D images.) He has 8 issued patents and 15 patents pending in the fields of display technology, computer graphics, material science and optics.

Huifang Sun *Ph.D., University of Ottawa, 1986*
MERL Fellow / IEEE Fellow

After four years as a Professor at Fairleigh Dickinson University, Huifang Sun moved to the Sarnoff Research Laboratory in 1990 becoming Technology Leader for Digital Video Communication. In 1995, Huifang joined MERL as the leader of our video efforts. In recognition of his productive career in video processing Huifang was made an IEEE Fellow in 2001. He was made a MERL Research Fellow in 2003.

Wei Sun *Ph.D., University of Waterloo, 2006*
Visiting Scientist

Prior to joining MERL in 2008, Wei Sun worked as a research fellow at the University of Waterloo for two years. His main research interests include multimedia security, biometrics, information security and privacy, compressive sensing and information theory. He also has a Ph.D. in cryptography and a Master degree in mathematics.

Zhifeng (Jeffrey) Tao *Ph.D., Polytechnic University, 2006*Principal Technical Staff

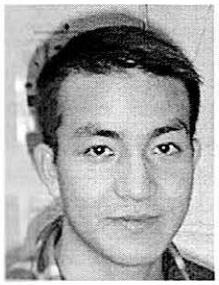
Zhifeng Tao joined MERL in September 2006. His research interests include wireless networking, medium access control, quality of service, cooperative communications and analytical modeling. He has been an active participant in IEEE 802.11n and 802.11s standardization since 2004, and is currently involved in developing the IEEE 802.16j and 802.16m.

Koon Hoo Teo *Ph.D., University of Alberta 1990*
Team Leader Ubiquitous Networks Group

Teo was with Nortel for about 15 years where he was actively involved in the research and implementation issues of a number of 3G and 4G wireless systems including Wireless Mesh Networks and WiMAX systems. His current research interests include Cognitive Radio, location tracking using Ultra Wideband technology, and Wireless Mesh and Multi-Hop Systems.

Jay E. Thornton *Ph.D., University of Michigan, 1982*
Group Manager Imaging

Thornton worked at Polaroid Corporation for many years, first in the Vision Research Laboratory and then as manager of the Image Science Laboratory. There, he worked on problems in color reproduction, image quality and image processing. He joined MERL in 2002 as Manager of the Computer Human Observation project, focusing on the computer vision problems that arise when computers analyze, measure, count, detect, and recognize people.

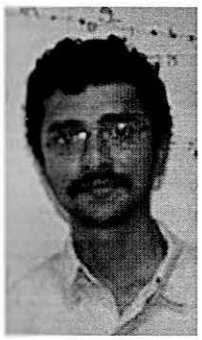


Kinh Tieu *Ph.D., Massachusetts Institute of Technology, 2006*
Visiting Scientist

Since getting his PhD Kinh has been a Research Fellow (in Radiology) at Brigham and Women's Hospital. At MERL, Kinh is working on problems of high speed image medical segmentation. He has also had a lot of experience in the application of statistical models to computer vision problems like multi-camera tracking.

C. Oncel Tuzel *Ph.D., Rutgers University, 2008*
Visiting Scientist

Oncel's doctoral worked focused on statistical learning techniques on smooth manifolds and their applications to scene analysis. He received the best paper runner-up award at CVPR 2007. His research interests are in computer vision, machine learning, pattern recognition, and computer graphics.



Ashok Veeraraghavan *Ph.D., Univ. of Maryland, College Park, 2008*
Research Scientist

Ashok's research interests are in signal, image and video processing, computer vision, pattern recognition and computational photography.

Anthony Vetro *Ph.D., Polytechnic University, 2001*
Group Manager Multimedia

Vetro joined MERL in 1996. His research interests are related to the encoding and transport of multimedia content. He has been an active participant in MPEG standards for several years. Dr. Vetro has contributed several technologies to MELCO products, including MPEG-2/4 transcoding for surveillance, post-filtering for artifact reduction and video down-decoding for a low-cost DTV receiver chip.

Gene V. Vinokur *M.S., Boston University, 2003*
Patent Agent

Prior to joining MERL, Vinokur spent four years at Putnam Investments developing software applications for the financial industry. He has been a licensed Patent Agent since 2003. He joined MERL's Patent Department in 2006.

Yebin Wang *Ph.D., University of Alberta, 2008*
Visiting Scientist

Prior to joining MERL, Yebin was a research assistant of Applied Nonlinear Control Laboratory of the Department of Electrical & Computer Engineering at the University of Alberta. Yebin's research interests include nonlinear observer/control design and applications, optimization, adaptive system, and mechatronics. He is a member of the IEEE.

Yige Wang *Ph.D., University of Hawaii at Manoa, 2008*
Visiting Scientist

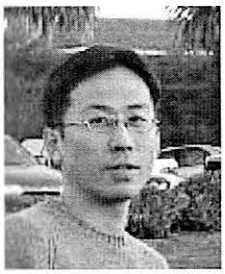
Yige Wang joined MERL in 2008. Her research interests include error control coding, digital communications, and VLSI implementation of communication algorithms. Her work has applications in the fields of optical communications, wireless communications, secure biometric systems, and IPTV systems.

Garrett Weinberg *B.A., Yale University, 2000*
Member Technical Staff

Before coming to MERL, Weinberg designed and internationalized automotive speech user interfaces at Dragon Systems, and was a chief architect and implementer of enterprise solutions for two Boston-area startups specializing, respectively, in Digital Rights Management and portfolio management. At MERL, he is leading the effort to port SpokenQuery technologies to various mobile and embedded platforms.

Kevin W. Wilson *Ph.D., Massachusetts Institute of Technology, 2006*
Member Technical Staff

For his doctoral thesis, Kevin Wilson incorporated aspects of the psychoacoustics of the precedence effect into an algorithm for computerized audio source localization. He is currently working on applications of signal processing and machine learning to audio processing, video processing and equipment condition monitoring.

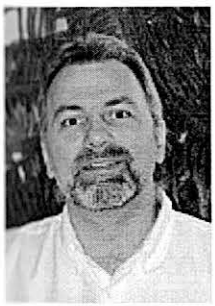


Sehoon Yea *Ph.D., Rensselaer Polytechnic Institute, 2006*
Principal Technical Staff

From 1996 to 2001, Yea was a Research Engineer at the Institute for Advanced Engineering in Korea, working on control systems such as industrial robots and servo-drivers. In the summer of 2004, he was an Intern with Sarnoff Corporation. Since joining MERL his work has focused on digital image and video compression, enhancement and communication.

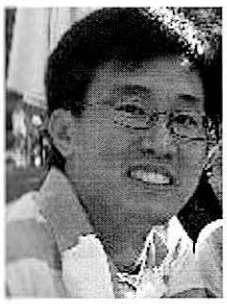
Jonathan S. Yedidia *Ph.D., Princeton University, 1990*
Distinguished Research Scientist

Yedidia's graduate work focused on theoretical condensed-matter physics, particularly the statistical mechanics of systems with quenched disorder. In 1997, he changed his focus to computer software and worked for a company called Viaweb on a shopping search engine, which has since become Yahoo's shopping service. At MERL since 1998, his particular interest is in the development of new methods belief propagation in constraint networks.



William S. Yerazunis *Ph.D., Rensselaer Polytechnic Institute, 1987*
Senior Research Scientist / Team Leader Hardware

Yerazunis has worked in a number of fields including: optics, vision processing, and signal processing, computer graphics, artificial intelligence parallel symbolic computation, radio astronomy and SETI, transplant immunology, virtual and augmented reality (Diamond Park and SPLINE), real-time sensing and ubiquitous computing, and real-time statistical categorization of text (for spam filtering).



Raymond Yim *Ph.D., Harvard University, 2006*
Research Scientist

Raymond has conducted successful research on the design and analysis of cross-layered architectures and protocols for wireless communication networks including cellular systems, wireless LANs, and sensor networks.

Jinyun Zhang *Ph.D., University of Ottawa, 1991*
Group Manager Digital Communication

Jinyun manages MERL's digital communications group. Before joining MERL in 2001, She worked for Nortel Networks for 10 years where she held engineering and management positions in the areas of VLSI design and advanced wireless & optical technology development. In recognition for her contributions to broadband wireless transmission and networking technology she became an IEEE Fellow in 2008.

Recent Major Publications

The following lists the major publications by members of the MERL staff. A publication is considered major if it appeared in a refereed journal, a refereed conference proceeding or some other significant publication such as a book.

An asterisk (*) appears before publications that are subject to highly stringent selection criteria where they were published. Some venues (such as major journals and certain key conferences) are very selective in what they publish and some (such as workshops and many conferences) are not. There are good reasons to publish something in a non-selective venue, the most important of which being that a given workshop or conference may be the best place at which to expose a particular piece of work to the scientific community. However, getting a piece of work into a highly selective venue is a mark of distinction that says a lot about the quality of the work in the eyes of the scientific community.

2009

Wang, Y.; Yedidia, J.S.; Draper, S.C., "Multi-stage Decoding of LCPC Codes", *IEEE International Symposium on Information Theory (ISIT)*, June 2009 (TR2009-029)

* Sengupta, K.; Porikli, F.M., "Geometric Sequence (GS) Imaging with Bayesian Smoothing for Optical and Capacitive Imaging Sensors", *IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops (CVPR)*, DOI 10.1109/CVPR.2009.5205205, pp. 90-97, June 2009 (TR2009-035)

Wang, T.; Tao, Z.; Molisch, A.F.; Orlik, P.V.; Zhang, J., "Adaptive Antenna Selection at Mobile Stations for SDMA in WiMAX Networks", *International Conference on Wireless Communications and Mobile Computing: Connecting the World Wirelessly (IWCMC)*, ISBN: 978-1-60558-569-7, pp. 586-591, June 2009 (TR2009-038)

Agrawal, A.; Xu, Y., "Coded Exposure Deblurring: Optimized Codes for PSF Estimation and Invertibility", *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, DOI: 10.1109/CVPRW.2009.5206685, Poster Session 5, pp. 2066-2073, June 2009 (TR2009-047)

Chang, J-Y; Raskar, R.; Agrawal, A., "3D Pose Estimation and Segmentation using Specular Cues", *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, DOI: 10.1109/CVPRW.2009.5206820, Poster Session 4, pp. 1706-1713, June 2009 (TR2009-043)

Reddy, D.; Agrawal, A.; Chellappa, R, "Enforcing Integrability by Error Correction using ℓ_1-minimization", *IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR)*, Poster Session 5, June 2009 (TR2009-044)

Joshi, A.J.; Porikli, F.M.; Papanikolopoulos, N., "Multi-Class Active Learning for Image Classification", *IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR)*, Poster Session 5, June 2009 (TR2009-034)

Agrawal, A.; Raskar, R., "Optimal Single Image Capture for Motion Deblurring", *IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR)*, Poster Session 6, June 2009 (TR2009-040)

Chang, R.Y.; Tao, Z.; Zhang, J.; Kuo, J., "A Graph Approach to Dynamic Fractional Frequency Reuse (FFR) in Multi-Cell OFDMA Networks", *IEEE International Conference on Communications (ICC)*, WCS-29: OFDMA II, June 2009 (TR2009-037)

Yim, R.; Molisch, A.F.; Zhang, J., "Optimization of Split-and-Combine Relaying", *IEEE International Conference on Communications (ICC)*, WCS-15: Cooperative Networks III, 2, June 2009 (TR2009-045)

Ma, J.; Orlik, P.V.; Zhang, J.; Kuze, T.; Iura, H.; Li, G-Y., "Pilot Matrix Design for Interim Channel Estimation in Two-Hop MIMO AF Relay Systems", *IEEE International Conference on Comm. (ICC)*, WCS-08: MIMO Cooperative Networks, 1, June 2009 (TR2009-042)

Shah, V.; Mehta, N.B.; Yim, R., "Analysis, Insights and Generalization of a Fast Decentralized Relay Selection Mechanism", *IEEE International Conference on Communications (ICC)*, WCS-04: Cooperative Networks II, 1, June 2009 (TR2009-046)

* El Rifai, K., "Nonlinearly Parameterized Adaptive PID Control for Parallel and Series Realizations", *American Control Conf. (ACC)*, Paper FrB18.3, June 2009 (TR2009-028)

* Vo, D.T.; Nguyen, T.Q.; Yea, S.; Vetro, A., "Adaptive Fuzzy Filtering for Artifact Reduction in Compressed Images and Videos", *IEEE Transactions on Image Processing (TIP)*, DOI: 10.1109/TIP.2009.2017169, Vol. 18, Issue 6, pp. 1166-1178, June 2009 (TR2009-022)

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Zhang, J.; Wang, Y.; Rong, B., "QoS/QoE Techniques for IPTV Transmissions", *IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB)*, ISBN: 978-1-4244-2590-7, pp. 1-6, May 2009 (TR2009-010)

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Yea, S.; Vetro, A., "Multi-layered Coding of Depth for Virtual View Synthesis", *Picture Coding Symp. (PCS)*, DOI 10.1109/PCS.2009.5167368, pp. 1-4, May 2009 (TR2009-033)

* Pun, M-O.; Brown, D.; Poor, H., "Opportunistic Collaborative Beamforming with One-Bit Feedback", *IEEE Transactions on Wireless Communications*, DOI: 10.1109/twc.2009.080512, Vol. 8, Issue 5, pp. 2629-2641, May 2009 (TR2009-049)

* Minegishi, N.; Sato, H.; Izhuara, F.; Koyama, M.; Vetro, A., "A Multi-Standards HDTV Video Decoder for Blu-Ray Disc Standard", *IEEE Transactions on Consumer Electronics*, DOI 10.1109/TCE.2009.5174422, Vol. 55, Issue 2, pp. 560-563, May 2009 (TR2009-041)

Ma, J.; Orlik, P.; Zhang, J.; Kuze, T.; Iura, H.; Li, G-Y., "Static Power Allocation in Two-Hop MIMO Amplify-and Forward Relay Systems", *IEEE Vehicular Technology Conference (VTC)*, 9Pa Transmission Technologies Poster IV, 10, April 2009 (TR2009-021)

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Thejaswi, C.; Pun, M-O.; Zhang, J.; Poor, H.V., "Distributed Opportunistic Scheduling with Two-Level Channel Probing", *IEEE Conference on Computer Communications (INFOCOM)*, April 2009 (TR2009-015)

* Duan, C.; Calle, V.H.C.; Khatri, S.P., "Efficient On-Chip Crosstalk Avoidance CODEC Design", *IEEE Transactions on Very Large Scale Integration (VLSI) Systems*, ISSN: 1063-8210, Vol. 17, Issue 4, pp. 551-560, April 2009 (TR2009-017)

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Gouvea, E.V.; Raj, B., "Word Particles Applied to Information Retrieval", *European Conference on Information Retrieval (ECIR)*, ISBN: 978-3-642-00957-0, pp. 424-436, April 2009 (TR2009-018)

* Yim, R.; Mehta, N.B.; Molisch, A.F., "Fast Multiple Access Selection through Variable Power Transmissions", *IEEE Transactions on Wireless Communications*, DOI: 10.1109/TWC.2009.080260, Vol. 8, Issue 4, pp. 1962-1973, April 2009 (TR2009-024)

Alsindi, N.; Duan, C.; Zhang, J.; Tsuboi, T., "NLOS Channel Identification and Mitigation in Ultra Wideband ToA-based Wireless Sensor Networks", *Workshop on Positioning, Navigation and Communication (WPNC)*, DOI: 10.1109/wpnc.2009.4907804, pp. 59-66. March 2009 (TR2009-006)

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Yea, S.; Vetro, A., "View Synthesis Prediction for Multiview Video Coding", *Image Comm.*, ISSN: 0923-5965, Vol. 24, Issue 1-2, pp. 89-100, January 2009 (TR2009-009)

* Jones, M.J., "Face Recognition: Where we are and where to go from here", *IEEJ Transactions on Electronic, Information and Systems*, ISSN: 1348-8155, Vol. 129 (2009), No. 5, pp. 770-777, January 2009 (TR2009-023)

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* Lanman, D.; Raskar, R.; Agrawal, A.; Taubin, G., "Shield Fields: Modeling and Capturing 3D Occluders", *ACM Transactions on Graphics (TOG)*, ISSN: 0730-0301, Vol. 27, Issue 5, Article 131, December 2008 (TR2008-085)

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Bhatti, G.M.; Mehta, A.; Sahinoglu, Z.; Zhang, J.; Viswanathan, R., "Modified Beacon-Enabled IEEE 802.15.4 MAC for Lower Latency", *Global Telecommunications Conference, 2008. (GLOBECOM)*, DOI: 10.1109/glocom.2008.ecp.173, pp. 1-5, November 2008 (TR2008-093)

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Eriksson, G.; Linder, S.; Wiklunh, K.; Holm, P.D.; Johansson, P.; Tufvesson, F.; Molisch, A.F., "Urban Peer-to-Peer MIMO Channel Measurements and Analysis at 300 MHz", *Military Communications Conference (MILCOM)*, DOI: 10.1109/MILCOM.2008.4753527, pp. 1-8, November 2008 (TR2008-076)

* Yim, R.; Mehta, N.B.; Molisch, A.F.; Zhang, J., "Progressive Accumulative Routing: Fundamental Concepts and Protocol", *IEEE Trans. on Wireless Comm.*, DOI: 10.1109/t-wc.2008.060224, Vol. 7, Issue 11, Part 1, pp. 4152-4154, November 2008 (TR2008-095)

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* Zhang, J.; Sun, H., "Wavelet-Based Multiscale Anisotropic Diffusion with Adaptive Statistical Analysis for Image Restoration", *IEEE Transactions on Circuits and Systems I: Regular Papers*, ISSN: 1549-8328, Vol. 55, Issue 9, pp. 2716-2725, October 2008 (TR2008-067)

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Jiang, H.; Wigdor, D.; Forlines, C.; Shen, C., "System Design for the WeSpace: Linking Personal Devices to a Table-Centered Multi-User, Multi-Surface Environment", *IEEE International Workshop on Horizontal Interactive Human Computer Systems, (TABLETOP)*, DOI: 10.1109/TABLETOP.2008.4660191, pp. 97-104, October 2008 (TR2008-068)

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Guvenc, I.; Gezici, S.; Sahinoglu, Z., "Ultra-wideband Range Estimation: Theoretical Limits and Practical Algorithms", *IEEE International Conference on Ultra-Wideband (ICUWB)*, DOI: 10.1109/ICUW.2008.4653424. vol. 3, pp. 93-96, September 2008 (TR2008-099)

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Guo, J.; Duan, C.; Bhatti, G.M.; Zhang, J., "Efficient Medium Access Protocol for Wireless Sensor Networks", *International Conference on Sensor Technologies and Applications (SENSORCOMM)*, ISBN: 978-0-7695-3330-8, pp. 13-17, August 2008 (TR2008-101)

* Madan, R.; Mehta, N.B.; Molisch, A.F.; Zhang, J., "Energy-Efficient Cooperative Relaying over Fading Channels with Simple Relay Selection", *IEEE Transactions on Wireless Comm.*, ISSN: 1536-1276, Vol. 7, Issue 8, pp. 3013-3025, August 2008 (TR2008-070)

* Raskar, R.; Agrawal, A.; Wilson, C.; Veeraraghavan, A., "Glare Aware Photography: 4D Ray Sampling for Reducing Glare Effects of Camera Lenses", *ACM Transactions on Graphics (TOG)*, ISSN:0730-0301, Volume 27 , Issue 3, August 2008 (TR2008-063)

* Fuchs, M.; Raskar, R.; Seidel, H-P.; Lensch, H.P.A., "Towards Passive 6D Reflectance Field Displays", ACM Transactions on Graphics (TOG), ISSN: 0730-0301, Vol. 27, Issue 3, Article 58, August 2008 (TR2008-098)

  Vetro, A.; Yea, S; Smolic, A., "Towards a 3D Video Format for Auto-Stereoscopic Displays", *SPIE Conference on Applications of Digital Image Processing XXXI*, Vol. 7073, September 2008 (TR2008-057)

  Matsumoto, W.; Kuze, T.: Uchida, S.; Hideo, Y.; Orlik, P.V.; Molisch, A.F.; Tao, Z.; Zhang, J., "Enhanced HARQ Technique Using Self-Interference Cancellation Coding (SICC)", *International Wireless Communications and Mobile Computing Conference (IWCMC)*, ISBN: 978-1-4244-2201 2, pp. 650-654, August 2008 (TR2008-097)

* Rubinstein, M.; Shamir, A.; Avidan, A., "Improved Seam Carving for Video Retargeting", *ACM Transactions on Graphics (TOG)*, ISSN: 0730-0301, Volume 27 , Issue 3, Article No. 16, August 2008 (TR2008-064)

  Weinberg, G.L.; Kondili, D., "Display Style Considerations for In-Car Multimodal Music Search", *IADIS International Conference Interfaces and Human Computer Interaction (IHCI)*, July 2008 (TR2008-038)

  Sutcu, Y.; Rane, S.D.; Yedidia, J.S.; Draper, S.C.; Vetro, A., "Feature Extraction for a Slepian-Wolf Biometric System Using LDPC Codes", *IEEE International Symposium on Information Theory (ISIT)*, DOI: 10.1109/ISIT.2008.4595400, pp. 2297-2301, July 2008 (TR2008-036)

Research

The body and soul of any research lab is the portfolio of research it pursues. Therefore it is appropriate that the main body of this annual report consists of descriptions of research projects being done at MERL. For ease of reference, the reports are grouped into six topic areas.

Digital Communications - High speed, low latency, and high reliability communications, channel modeling, advanced channel coding/decoding, and next generation standards & new applications.

Multimedia – Efficient representation, transmission, security, processing and interaction of multimedia; including video compression, display processing, information coding for security, compressive sensing, and speech processing.

Data Analytics - Predictive analytics (statistical machine learning, data analysis); decision analytics (optimization and control); and software infrastructure (distributed software systems, data stream processing).

Imaging - Developing and applying novel methods for sensing people, objects & events; algorithms for detection, recognition, and classification; 3D modeling and computer graphics; image and video processing; optics and other sensors (PIR motion, force, ultrasound, SAR, etc.).

Mechatronics - Advanced control algorithms, system dynamics, modeling & performance analysis, mechatronics design, innovative system concepts, and 2D/3D adaptively-sampled distance fields applications.

Algorithms - Solution methods for optimization problems involving very large numbers of variables in the areas of information theory & coding; stochastic network utility maximization; sensing, perception, inference & learning.

Each research area section starts with a short discussion of the topic area highlighting MERL's major efforts and serving as an index into the more detailed descriptions of MERL's recent work that follow.

Digital Communications

Digital communications and networking are pervasive in today's society. Advanced technologies at the physical layer, medium access control layer and network layer provide high speed communication capability for transmissions of voice, data, and multimedia information with quality of service over wire or wireless, connecting people anywhere at anytime. From advanced wireless multimedia systems to simple integrated home networking, communications and networking technologies are at the center of a continuing revolution.

At MERL, we are conducting fundamental research on communication theories and applied research on cutting-edge technologies in the area of digital communications and networking. Our goal is to identify new technology trends and business opportunities, create core technologies, apply our discoveries to emerging products, and contribute to international standards and the scientific community.

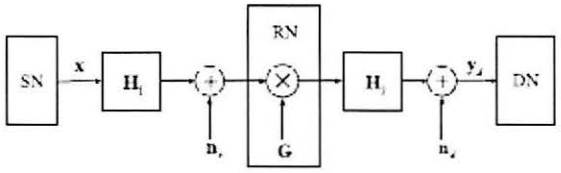
We have been focusing on broadband communication technologies, including MIMO (Multi-Input-Multi-Output), antenna selection, multi-hop relaying and interference management, for wireless infrastructure standards and systems such as 3GPP LTE and advanced WiMAX. We have also done fundamental research in the area of short-range communications, ad-hoc networking, and precision location technologies for home networks, building automation and energy saving.

Recent Research

Pilot Matrix Design for Interim Channel Estimation in Two-Hop MIMO AF Relay Systems

Citation: Ma, J.; Orlik, P.; Zhang, J.; Kuze, T.; Iura, H.; Li, G-Y., "Pilot Matrix Design for Interim Channel Estimation in Two-Hop MIMO AF Relay Systems", *IEEE International Conference on Communications (ICC)*, June 2009

Contacts: Philip Orlik, Jinyun Zhang

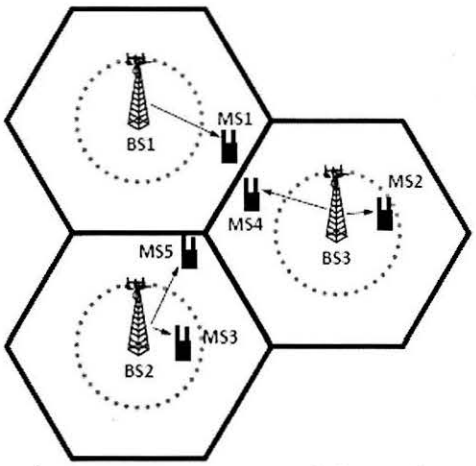


In this paper, we are concerned with a two-hop *multi-input-multi-output* (MIMO) *amplify-and-forward* (AF) relay system consisting of a source node (SN), a relay node (RN), and a destination node (DN). Since the simple RN in this system is unaware of the structure of its received signal and incapable of performing complicated signal processing, the interim channels over the SN-RN and the RN-DN hops can not be estimated directly. Therefore, we develop a novel interim channel estimation approach in this paper. Furthermore, we find necessary and sufficient conditions for the pilot amplifying matrix sequence at the RN to ensure successful interim channel estimation at the DN, and present rules to design low-complexity pilot amplifying matrices meeting these conditions.

A Graph Approach to Dynamic Fractional Frequency Reuse (FFR) in Multi-Cell OFDMA Networks

Citation: Chang, R.Y.; Tao, Z.; Zhang, J.; Kuo, J., "A Graph Approach to Dynamic Fractional Frequency Reuse (FFR) in Multi-Cell OFDMA Networks", *IEEE International Conference on Communications (ICC)*, June 2009

Contacts: Zhifeng Tao, Jinyun Zhang

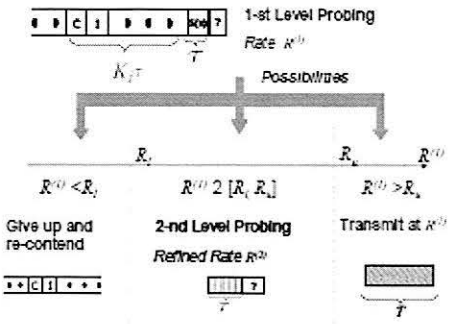


Dynamic fractional frequency reuse (FFR) in multi-cell OFDMA networks is a promising resource allocation technique that can effectively mitigate inter-cell interference (ICI). Our approach enhances the conventional FFR by enabling adaptive spectral sharing per cell load conditions offering significant benefits in a practical environment where traffic load in different cells may be asymmetric and time-varying. The dynamic feature is accomplished by translating the resource allocation problem to a graph coloring problem. We further demonstrate the resulting performance improvement by computer simulation for a 19-cell network with asymmetric cell load. For instance, our proposed dynamic FFR scheme can achieve a 12% and 33% gain in cell throughput and service rate over conventional FFR, and render a 70% and 107% gain in cell throughput and service rate with respect to the reuse-3 system.

Distributed Opportunistic Scheduling with Two-Level Channel Probing

Citation: Thejaswi, C.; Pun, M-O.; Zhang, J.; Poor, H.V., "Distributed Opportunistic Scheduling with Two-Level Channel Probing", *IEEE Conference on Computer Communicaitons (INFOCOM)*, April 2009

Contacts: Man-On Pun, Jinyun Zhang

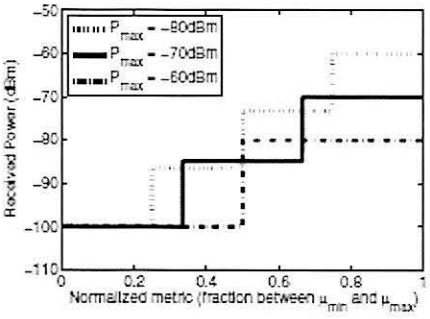


Distributed opportunistic scheduling (DOS) involves a process of joint channel probing and distributed scheduling for ad-hoc (peer-to-peer) communications. This work investigates DOS with two-level channel probing by optimizing the tradeoff between the throughput gain from more accurate rate estimation and the resulting additional delay. Capitalizing on optimal stopping theory with incomplete information, we show that the optimal scheduling policy is threshold-based and is characterized by either one or two thresholds, depending on network settings. We rigorously establish the necessary and sufficient conditions for both cases. Our analysis reveals that performing second-level channel probing is optimal when the first-level estimated channel condition falls between the two thresholds. Finally, we provide numerical results to illustrate the effectiveness of the proposed DOS with two-level channel probing.

Fast Multiple Access Selection through Variable Power Transmissions

Citation: Yim, R.; Mehta, N.B.; Molisch, A.F., "Fast Multiple Access Selection through Variable Power Transmissions", *IEEE Transactions on Wireless Communications*, ISSN: 1536-1276, Vol. 8, Issue 4, pp. 1962-1973, April 2009

Contact: Raymond Yim

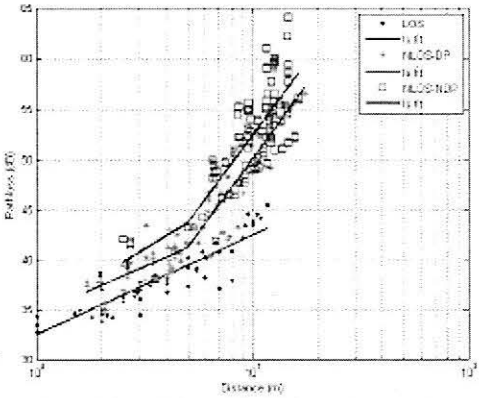


We introduce an extremely fast contention-based multiple access algorithm that selects the best node (highest priority) and requires only local information of the node priorities. Our Variable Power Multiple Access Selection (VP-MAS) approach uses the local channel state information from the accessing nodes to the receiver, based on a key result that mapping onto a set of discrete receive power levels is optimal when the power levels are chosen to exploit packet capture which inherently occurs in a wireless physical layer. VP-MAS adjusts the expected number of users that contend in each step and their respective transmission powers, depending on whether previous transmission attempts resulted in capture, idle channel, or collision. We also show how reliable information regarding the total received power at the receiver can be used to improve the algorithm by enhancing the feedback mechanism.

NLOS Channel Identification and Mitigation in Ultra Wideband ToA-based Wireless Sensor Networks

Citation: Duan, C.; Alsindi, N.; Zhang, J., "NLOS Channel Identification and Mitigation in Ultra Wideband ToA-based Wireless Sensor Networks", *Workshop on Positioning, Navigation and Communicaiton (WPNC)*, March 2009

Contacts: Chunjie Duan, Jinyun Zhang

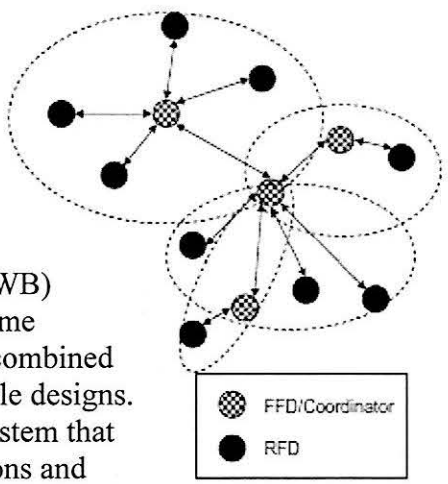


Localization performance in a typical Wireless Sensor Network (WSN) operating in an indoor environment can degrade considerably due to the existence of non-line-of-sight (NLOS) channel conditions between the sensor nodes. Under such conditions the ranging accuracy degrades with the attenuation and/or loss of the Direct Path (DP) signal which ultimately imposes a positive bias on the Time of Arrival (ToA)-based distance estimation. We propose a novel, low complexity wireless channel condition estimation algorithm that identifies the condition of the channel. Based on the estimated ToA and Received Signal Strength (RSS) our algorithm identifies the channel condition, which can be either LOS, NLOS-DP available, or NLOS-DP not available. Simulation results show that our estimator has robust performance with success rates of 85%. The simulations also show that by taking advantage of the channel condition estimation, we are able to reduce the RMSE of the localization estimate by over 40%.

UWB Systms for Wireless Sensor Networks

Citation: Zhang, J.; Orlik, P.; Sahinoglu, Z.; Molisch, A.F.; Kinney, P., "UWB Systms for Wireless Sensor Networks", *Proceedings of the IEEE*, ISSN: 0018-9219, Vol. 97, Issue 2, pp. 313-331, February 2009

Contacts: Jinyun Zhang, Philip Orlik, Zafer Sahinoglu



Wireless sensor networks are emerging as an important area for communications to enable a wealth of new applications including surveillance, building control, factory automation, and in-vehicle sensing. The sensor nodes must operate under severe constraints on energy consumption and form factor, and provide the ability for precise node self-location. We discuss various techniques and trade-offs in ultra wideband (UWB) systems to meet these requirements, and we demonstrate that time hopping and frequency hopping impulse radio physical layers combined with simple multiple-access techniques like ALOHA are suitable designs. We also describe the IEEE 802.15.4a standard, an important system that adopts UWB impulse radio to ensure robust data communications and precision ranging. In order to accommodate heterogeneous networks, it uses specific modulation, coding and ranging waveforms that can be detected well by both coherent and non-coherent receivers.

Propagation Aspects of Vehicle-to-Vehicle Communications - An Overview

Citation: Molisch, A.; Turfvesson, F.; Karedal, J.; Mecklenbrauker, C., "Propagation Aspects of Vehicle-to-Vehicle Communications - An Overview", *IEEE Radio & Wireless Symposium*, January 2009

Contact: Jinyun Zhang

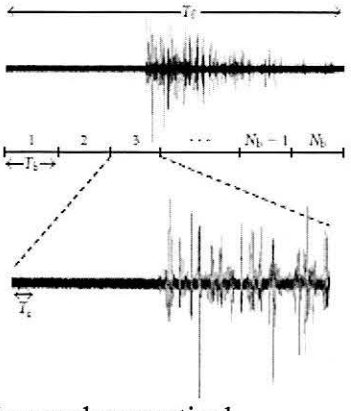
$$S(f) = \frac{\sigma_1^2}{\pi^2 f_{\max,TX}\sqrt{a}} K\left(\frac{1+a}{2\sqrt{a}}\sqrt{1-\left(\frac{f}{(1+a)f_{\max,TX}}\right)^2}\right)$$

Vehicle-to-vehicle (VTV) wireless communications have many envisioned applications in traffic safety, congestion avoidance, etc., but the development of suitable communications systems and standards requires accurate models for the VTV propagation channel. This paper provides an overview of existing VTV channel measurement campaigns, describing the most important environments, and the delay spread and Doppler spreads obtained in them. Statistical as well as geometry-based channel models have been developed based on measurements and intuitive insights. A key characteristic of VTV channels is the nonstationarity of their statistics, which has major impact on the system performance. Extensive references are provided.

Two-Step Time of Arrival Estimation for Pulse-Based Ultra-Wideband Systems

Citation: Gezici, S.; Sahinoglu, Z.; Molisch, A.F.; Kobayashi, H.; Poor, H.V., "Two-Step Time of Arrival Estimation for Pulse-Based Ultra-Wideband Systems", *EURASIP Journal on Advances in Signal Processing*, Vol. 2008, Article ID 529134, 11 pages, doi:10.115/2008/529134, December 2008

Contact: Zafer Sahinoglu

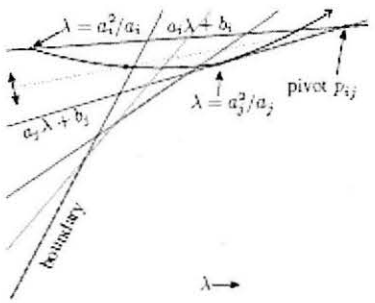


In cooperative localization systems, wireless nodes need to exchange accurate position-related information such as time-of-arrival (TOA) and angle-of-arrival (AOA), in order to obtain accurate location information. One alternative for providing accurate position-related information is to use ultra-wideband (UWB) signals. The high time resolution of UWB signals presents a potential for very accurate positioning based on TOA estimation. However, it is challenging to realize very accurate positioning systems in practical scenarios, due to both complexity/cost constraints and adverse channel conditions such as multipath propagation. We propose a two-step TOA estimation algorithm for UWB systems in order to provide accurate TOA estimation under practical constraints using low-rate correlation outputs.

Delay-Energy Tradeoffs in Wireless Ad-Hoc Networks with Partial Channel State Information

Citation: Brand, M.; Molisch, A.F., "Delay-Energy Tradeoffs in Wireless Ad-Hoc Networks with Partial Channel State Information", *IEEE Global Telecommunications Conference (GLOBECOM)*, ISSN 1930-529X, pp 1-6, November 2008

Contact: Matthew Brand

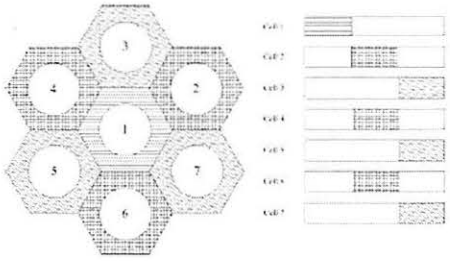


Given a wireless network where each link undergoes small-scale (Rayleigh) fading, we consider the problem of routing a message from a source node to a target node while minimizing energy or power expenditure under a fixed time budget, or vice versa. Given instantaneous channel state information, we develop tight hyperbolic bounds on the quantities of interest and solve the related optimizations in closed form or via lightweight computations. If only average channel state information is available, probabilistical performance measures provide another set of bounds that supports resource-optimal routing with a guaranteed success probability. Our results rest on novel formulations and solution methods for hyperbolic convex programs and nonlinear multicriterion combinatorial optimization.

Adaptive Soft Frequency Reuse for Inter-cell Interference Coordination in SC-FDMA based 3GPP LTE Uplinks

Citation: Mao, X.; Maaref, A.; Teo, K.H., "Adaptive Soft Frequency Reuse for Inter-cell Interference Coordination in SC-FDMA based 3GPP LTE Uplinks", *IEEE Global Telecommunications Conference (GLOBECOM)*, ISSN: 1930-529X, pp. 1-6, November 2008

Contact: Koon Hoo Teo

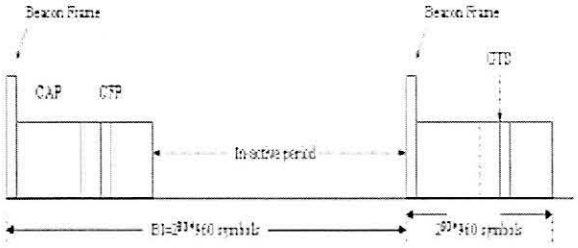


We propose a decentralized adaptive soft frequency reuse scheme for the uplink of 4G long-term evolution (LTE) systems. While universal frequency reuse (UFR) is being targeted for next generation multi-cellular wireless networks, ongoing efforts supporting the LTE standard have proven that actual implementations of UFR in LTE lead to unacceptable interference levels experienced near the cell edge area in a multi-cellular configuration. Our adaptive soft frequency reuse solution implements physical resource block (PRB) reuse avoidance/minimization and cell-edge bandwidth breathing which can be implemented at the cost of a negligible information exchange over the X2 interface (backbone). PRB reuse avoidance significantly decreases inter-cell interference levels while improving the achievable average throughput per user, especially at the cell-edge. The cell-edge bandwidth breathing strategy tracks and adapts to semi-static changes in traffic loading and user distributions within each cell to drastically reduce the blocking probability of incoming calls under cell-edge bandwidth constrained traffic.

Modified Beacon-Enabled IEEE 802.15.4 MAC for Lower Latency

Citation: Bhatti, G.; Mehta, A.; Sahinoglu, Z.; Zhang, J.; Viswanathan, R., "Modified Beacon-Enabled IEEE 802.15.4 MAC for Lower Latency", *Global Telecommunications Conference, 2008. (GLOBECOM 2008)*, ISBN: 978-1-4244-2324-8, November 30 2008

Contacts: Ghulam Bhatti, Zafer Sahinoglu, Jinyun Zhang

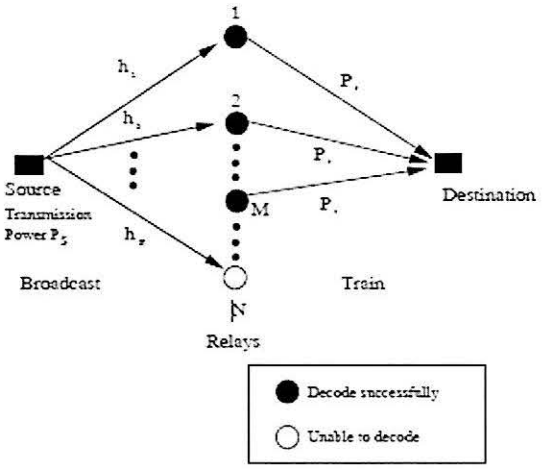


Offering a high degree of flexibility at a lower cost, wireless networks can offer an attractive and viable communications solution for industrial sensing and automation. The IEEE 802.15.4 standard defines a specification for MAC and PHY layers for shortrange, low bit-rate, and low-cost wireless networks. However, the specified system is inefficient in terms of latency and reliability and fails to meet the stringent operational requirements for industrial applications. In this paper, we propose a set of new MAC superframes with an aim to enhance both performance metrics. We then use simulation to compare the performance of our proposed systems with that of the one specified in the IEEE 802.15.4 standard.

Energy-Efficient Cooperative Relaying over Fading Channels with Simple Relay Selection

Citation: Madan, R.; Mehta, N.B.; Molisch, A.F.; Zhang, J., "Energy-Efficient Cooperative Relaying over Fading Channels with Simple Relay Selection", *IEEE Transactions on Wireless Communications*, ISSN: 1536-1276, Vol. 7, Issue 8, pp. 3013-3025, August 2008

We consider a wireless network where a set of nodes cooperate to relay data in parallel from a source to a destination using a decode-and-forward approach. The source broadcasts data to the relays, some or all of which cooperatively beamform to forward the data to the destination. We generalize the standard approaches for cooperative communications in two key respects: (i) we explicitly model and factor in the cost of acquiring channel state information (CSI), and (ii) we consider more general selection rules for the relays and compute the optimal one among them. We obtain expressions for the total energy consumption for general relay selection and outage criteria for the non-homogeneous case, in which different relay links have different mean channel power gains, and the homogeneous case, in which the relay links statistics are identical. Depending on the relative location of the relays, the source, and the destination, numerical computations show energy savings of about 16% when an optimal relay selection rule is used.



Multimedia

Multimedia research at MERL is centered on the efficient representation, processing and security of multimedia as well as enhanced interactions with multimedia. Core technical strengths include digital video, information coding and speech/audio processing.

The digital video area includes both compression and display processing work. A key goal is to improve the compression efficiency of rich video formats, e.g., multiple views and 3D scene information, higher resolution, full color sampling, and greater bit-depth. We also conduct research on the various display processing functions including video noise reduction and format conversions. Our research results are applied to international standards and across a wide range of audio-visual products. We also consider proprietary coding schemes that are applied to closed systems such as surveillance and satellite.

Our research in the area of information coding considers coding technology for both security and sensing applications. We actively explore the application of distributed source coding principles to problems in the security area, such as the secure storage of biometric data. Data hiding is another area of study for authentication and copyright infringement of documents and media. A major research initiative is on a class of technology to perform signal processing of encrypted data. We are also exploring fundamental technology and applications of compressive sensing.

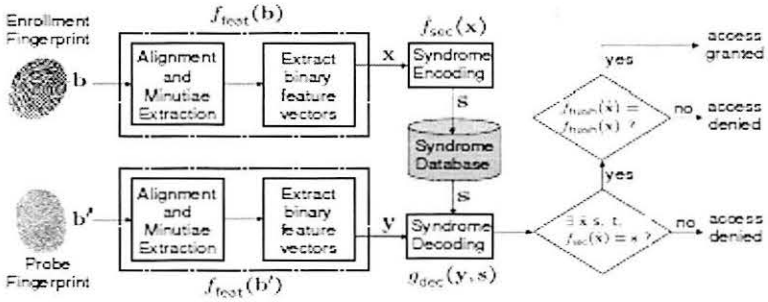
The work on speech and audio processing emphasizes spoken-language interfaces for automotive and handheld devices. There is ongoing research on using acoustic Doppler features to enhance speech, as well as technology that aims to improve multimodal interfaces. Our work in this area has been primarily applied to car navigation products.

Recent Research

Securing Biometric Data

Citation: Vetro, A.; Draper, S.; Rane, S.; Yedidia, J., "Securing Biometric Data", *Distributed Source Coding*, ISBN-13: 978-0-12-374485-2 Algorithms and Applications, January 2009

Contacts: Anthony Vetro, Shantanu Rane, Jonathan Yedidia



This chapter discusses the application of distributed source coding techniques to biometric security. A Slepian-Wolf coding system is used to provide a secure means of storing biometric data that provides robust biometric authentication for genuine users and guards against attacks from imposters. A formal quantification of the trade off between security and robustness is provided as a function of the Slepian-Wolf coding rate. Prototype secure biometric designs are presented for both iris and fingerprint modalities. These designs demonstrate that it is feasible to achieve information-theoretic security while not significantly compromising authentication performance (measured in terms of false-rejection and false-acceptance rates) when compared to conventional biometric systems. The methods described in this chapter can be applied to various architectures, including secure biometric authentication for access control and biometric-based key generation for encryption.

Data Hiding in Hard-Copy Text Documents Robust to Print, Scan, and Photocopy Operations

Citation: Varna, A.L.; Rane, S.; Vetro, A., "Data Hiding in Hard-Copy Text Documents Robust to Print, Scan, and Photocopy Operations", *IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, April 2009

Contacts: Shantanu Rane, Anthony Vetro

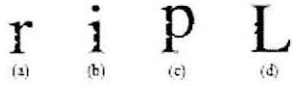


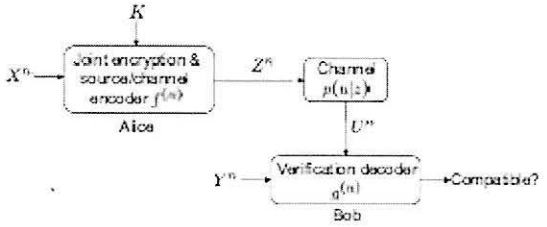
Fig. 1. Characters with different embedded symbols at 300% magnification. The distance between the notches or bumps encodes a symbol.

This paper describes a method for hiding data inside printed text documents that is resilient to print/scan and photocopying operations. Using the principle of channel coding with side information, the embedder inserts a message into a text document while treating the content of the document as known interference. The data is embedded by making small changes to text characters before the document is printed. Using a simple correlation-based detector in conjunction with an error correction code, the hidden data can be extracted from a photocopy of the printed document. By enhancing the detector with an optical character recognition algorithm, the embedded data can be extracted even after multiple rounds of photocopying. Resultsfrom subjective tests show that the changes made by the embedding algorithm, while perceptible, are not obtrusive to a lay reader.

On Information Leakage during Secure Verification of Campatibility between Signals

Citation: Sun, W.; Rane, S., "On Information Leakage during Secure Verification of Campatibility between Signals", *Canadian Workshop on Information Theory (CWIT)*, ISBN: 978-1-4244-3400-8, pp. 75-78, May 2009

Contacts: Wei Sun, Shantanu Rane

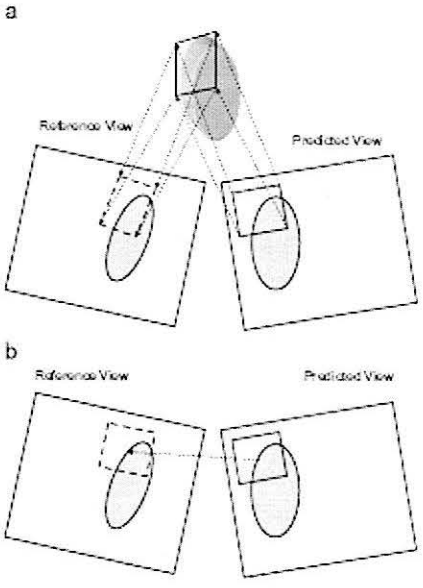


We consider a secure verification problem in which Alice wants to verify whether her signal X^n is compatible with Bob's signal Y^n, where X^n and Y^n are drawn i.i.d. according to a joint distribution $p(x, y)$. The notion of compatibility is defined as the requirement that $p(x, y)$ belongs to a certain set A of allowable joint distributions. For privacy, Alice jointly encrypts and encodes X^n and transmits the result over a public channel to Bob. Using the information leaked by the encryption algorithm, Bob verifies the compatiblility of X^n with Y^n. We characterize the minimum information that Alice's encryption and coding algorithm must leak in order to guarantee reliable verification results. Further, we determine the maximum information that Bob can hope to extract about X^n if he is curious. It is shown that a source/channel separation theorem holds for this scenario.

View Synthesis Prediction for Multiview Video Coding

Citation: Yea, S.; Vetro, A., "View Synthesis Prediction for Multiview Video Coding", *Image Communication*, ISSN: 0923-5965, Vol. 24, Iss. 1-2, pp. 89-100, Jan 2009

Contacts: Sehoon Yea, Anthony Vetro



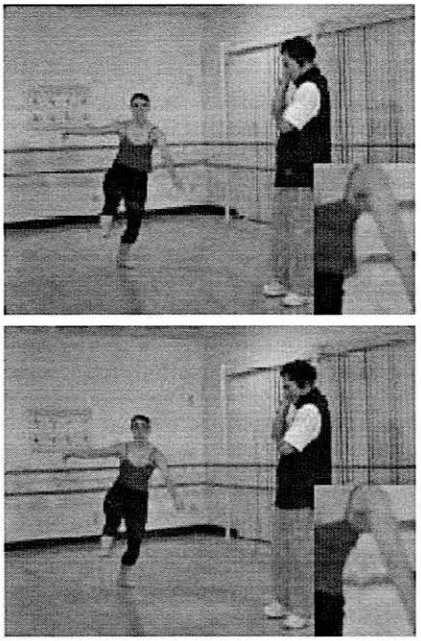
We propose a rate-distortion-optimized framework that incorporates view synthesis for improved prediction in multiview video coding. Auxiliary information, including depth data, is encoded and used at the decoder to generate the view synthesis prediction data. Our method employs optimal mode decision including view synthesis prediction, and sub-pixel reference matching to improve prediction accuracy of the view synthesis prediction. We also present novel variants of the skip and direct modes, which infer the depth and correction vector information from neighboring blocks in a synthesized reference picture to reduce the bits needed for the view synthesis prediction mode. We demonstrate two multiview video coding scenarios in which view synthesis prediction is employed.

Hole-Filling Method Using Depth Based In-Painting for View Synthesis in Free Viewpoint Television (FTV) and 3D Video

Citation: Oh, K.-J.; Yea, S.; Ho, Y.-S., "Hole-Filling Method Using Depth Based In-Painting for View Synthesis in Free Viewpoint Television (FTV) and 3D Video", *Picture Coding Symposium (PCS)*, May 2009

Contact: Sehoon Yea

Depth image-based rendering (DIBR) is generally used to synthesize a virtual view in free viewpoint television (FTV) and 3D video. One of the key techniques in DIBR is how to fill the holes caused by disocclusion regions and wrong depth values. In this paper, we propose a new hole-filling method using depth-based in-painting. The proposed method is designed by combining the depth-based holefilling and the in-painting. From the experiments, we confirm that the proposed hole-filling method provides better rendering quality objectively and subjectively.



Multi-layered Coding of Depth for Virtual View Synthesis

Citation: Yea, S.; Vetro, A., "Multi-layered Coding of Depth for Virtual View Synthesis", *Picture Coding Symposium (PCS)*, DOI 10.1109/PCS.2009.5167368, pp. 1-4, May 2009

Contacts: Sehoon Yea, Anthony Vetro

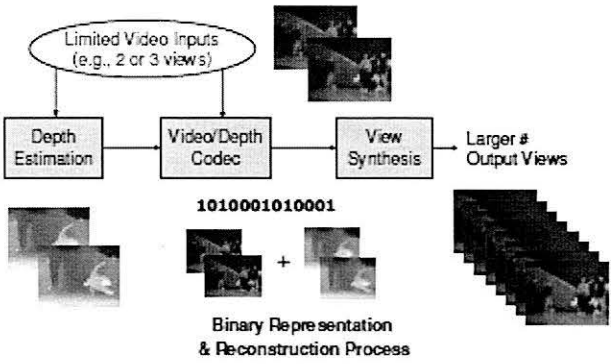
It is well-known that large depth-coding errors typically occurring around depth edge areas lead to distorted object boundaries in the synthesized texture images. This paper proposes a multi-layered coding approach for depth images as a complement to the popular edge-aware approaches such as those based on platelets. It is shown that guaranteeing a near-lossless bound on the depth values around the edges by adding extra enhancement layers is an effective way to improve the visual quality of the synthesized images.

(a) Map of depth coding error ($\delta \geq 4$)

Towards a 3D Video Format for Auto-Stereoscopic Displays

Citation: Vetro, A.; Yea, S; Smolic, A., "Towards a 3D Video Format for Auto-Stereoscopic Displays", *SPIE Conference on Applications of Digital Image Processing XXXI*, Vol. 7073, September 2008

Contacts: Anthony Vetro, Sehoon Yea

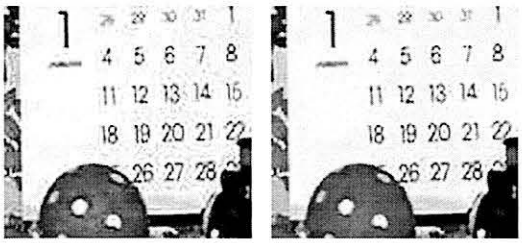


To avoid the need for specialized glasses and realize high quality auto-stereoscopic displays, multiple views of the video content must either be provided as input to the display, or these views must be created locally at the display. The former approach has difficulties in that the production environment is typically limited to stereo, and transmission bandwidth for a large number of views is not likely to be available. This paper discusses an emerging 3D data format that enables the latter approach—creating multiple views locally at the display. A new framework for efficiently representing a 3D scene and enabling the reconstruction of an arbitrarily large number of views prior to rendering is introduced. Several design challenges are also highlighted through experimental results.

Adaptive Fuzzy Filtering for Artifact Reduction in Compressed Images and Videos

Citation: Vo, D.T.; Nguyen, T.Q.; Yea, S.; Vetro, A., "Adaptive Fuzzy Filtering for Artifact Reduction in Compressed Images and Videos", *IEEE Transactions on Image Processing*, ISSN: 1057=7149, Vol. 18, Issue 6, June 2009

Contacts: Sehoon Yea, Anthony Vetro

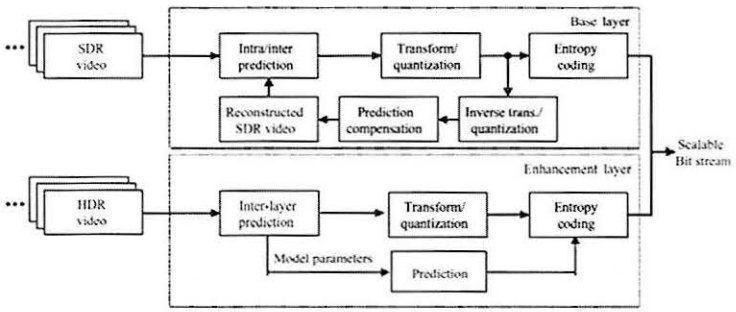


A fuzzy filter adaptive to both sample's activity and the relative position between samples is proposed to reduce the artifacts in compressed multidimensional signals. For JPEG images, the fuzzy spatial filter is based on the directional characteristics of ringing artifacts along the strong edges. For compressed video sequences, the motion compensated spatiotemporal filter (MCSTF) is applied to intraframe and interframe pixels to deal with both spatial and temporal artifacts. A new metric which considers the tracking characteristic of human eyes is proposed to evaluate the flickering artifacts. Simulations on compressed images and videos show improvement in artifact reduction of the proposed adaptive fuzzy filter over other conventional spatial or temporal filtering approaches.

Bit-depth Scalable Coding for High Dynamic Range Video

Citation: Liu, S.; Kim, W-S.; Vetro, A., "Bit-depth Scalable Coding for High Dynamic Range Video", *SPIE Conference on Visual Communications and Image Processing (VCIP)*, Vol. 6822, January 2008

Contact: Anthony Vetro

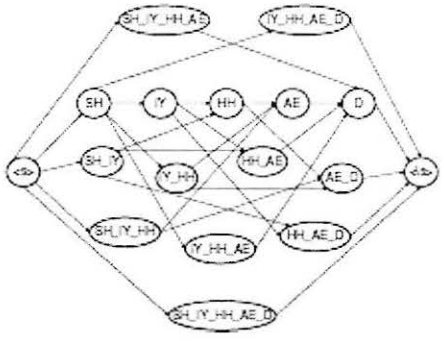


This paper presents a technique for coding high dynamic range videos. The proposed coding scheme is scalable, such that both standard dynamic range and high dynamic range representations of a video can be extracted from one bit stream. A localized inverse tone mapping method is proposed for efficient inter-layer prediction, which applies a scaling factor and an offset to each macroblock, per color channel. The scaling factors and offsets are predicted from neighboring macroblocks, and then the differences are entropy coded. The proposed inter-layer prediction technique is independent of the forward tone mapping method and is able to cover a wide range of bit-depths and various color spaces. Simulations are performed based on H.264/AVC SVC common software and core experiment conditions. Results show the effectiveness of the proposed method.

Word Particles Applied to Information Retrieval

Citation: Gouvea, E.V.; Raj, B., "Word Particles Applied to Information Retrieval", *European Conference on Informaiton Retrieval (ECIR)*, April 2009

Contact: Evandro Gouvea

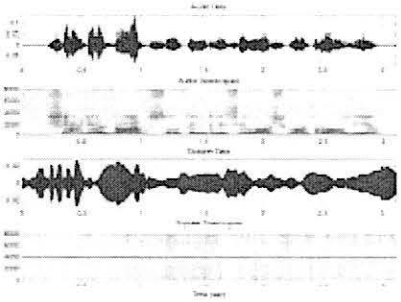


Document retrieval systems conventionally use words as the basic unit of representation, a natural choice since words are primary carriers of semantic information. In this paper we propose the use of a different, phonetically defined unit of representation that we call "particles". Particles are phonetic sequences that do not possess meaning. Both documents and queries are converted from their standard wordbased form into sequences of particles. Indexing and retrieval is performed with particles. Experiments show that this scheme is capable of achieving retrieval performance that is comparable to that from words when the text in the documents and queries are clean, and can result in significantly improved retrieval when they are noisy.

Ultrasonic Doppler Sensor for Speaker Recognition

Citation: Kalgaonkar, K.; Raj, B., "Ultrasonic Doppler Sensor for Speaker Recognition", *IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, ISSN: 1520-6149, pp. 4865-4868, March 2008

Contact: Kevin Wilson



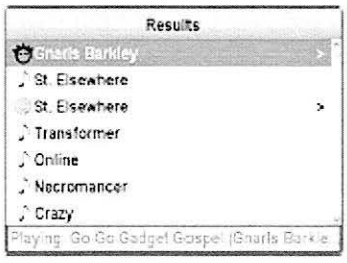
In this paper we present a novel use of an acoustic Doppler sonar for multi-modal speaker identification. An ultrasonic emitter directs a 40kHz tone toward the speaker. Reflections from the speaker's face are recorded as the speaker talks. The frequency of the tone is modified by the velocity of the facial structures it is reflected by. The received ultrasonic signal thus contains an entire spectrum of frequencies representing the set of all velocities of facial components. The pattern of frequencies in the reflected signal is observed to be typical of the speaker. The captured ultrasonic signal is synchronously analyzed with the corresponding voice signal to extract specific characteristics that can be used to identify the speaker. Experiments show that the information this can result in significant improvements in speaker identification accuracy both under clean conditions and in noise.

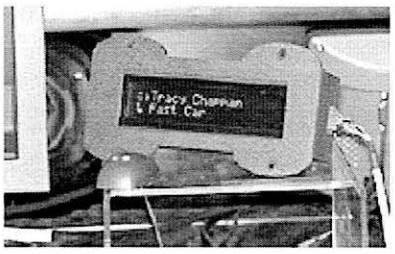
Display Style Considerations for In-Car Multimodal Music Search

Citation: Weinberg, G.; Kondili, D., "Display Style Considerations for In-Car Multimodal Music Search", *IADIS International Conference Interfaces and Human Computer Interaction (IHCI)*, Jul 2008

Contact: Garrett Weinberg

Figure 1. Left: Top seven results for query "gnarls barkley saint elsewhere" on interface variant A. Right: Top two results for query "tracy chapman fast car" on interface variant B.



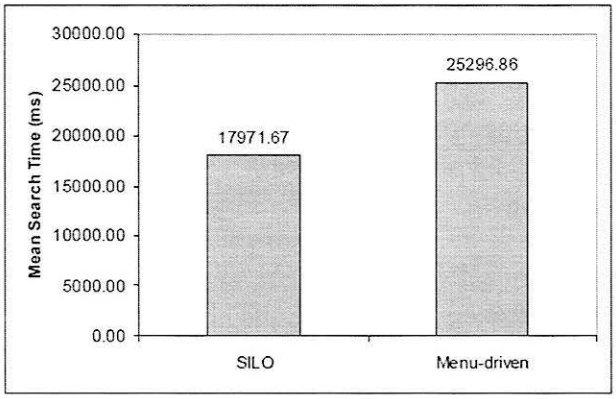


In this pilot study, the authors employed a basic driving simulator to examine both driving behavior and task performance as subjects performed music retrieval tasks using one of three variants of the "SpeakPod" voice search prototype. The variants shared speech and manual interface designs but differed in visual output capabilities. Preliminary data indicate that the chosen variant and the presence or absence of a music search task had little impact on the chosen driving metric. Post-drive NASA-TLX survey results do not show any of the three variants to be any more cognitively demanding than any other. There was also no clear winner in terms of task success rate.

Speech-Based UI Design for the Automobile

Citation: Schmidt-Nielsen, B.; Harsham, B.; Raj, B.; Forlines, C., "Speech-Based UI Design for the Automobile", *Handbook of Research on User Interface Design and Evaluation for Mobile Technology*, ISBN: 978-1-59904-871-0, Vol. 1, Chapter XV, pp. 237-252, February 2008

Contacts: Bent Schmidt-Nielsen, Bret Harsham, Clifton Forlines



In this chapter we discuss a variety of topics relating to speech-based user interfaces for use in an automotive environment. We begin by presenting a number of design principles for the design of such interfaces, derived from several decades of combined experience in the development and evaluation of spoken user interfaces (UI) for automobiles, along with three case studies of current automotive navigation interfaces. Finally, we present a new model for speech-based user interfaces in automotive environments that recasts the goal of the UI from supporting the navigation among and selection from multiple states to that of selecting the desired command from a short list. We also present experimental evidence that UIs based on this approach can impose significantly lower cognitive load on a driver than conventional UIs.

Data Analytics

The advent of powerful embedded computing, ubiquitous communications, and inexpensive sensors has led to a tidal wave of streaming data coming from both industrial installations and enterprise and public IT systems. The field of data analytics is concerned with harnessing the power and extracting the value of information hidden in such data streams to enable better decision making. This in turn makes it possible to minimize costs, maximize profits, increase reliability, improve energy efficiency, and reduce environmental impact of products. The Data Analytics group at MERL has been working in all three areas of analytics (predictive, decision, and visual), as well as supporting fields such as signal processing and information systems infrastructure. The focus of the group is on innovative high-performance algorithms that can be applied to the product lines of Mitsubishi Electric.

Research on predictive analytics, supported by advances in the field of statistical machine learning, aims to create accurate data-driven models of electromechanical systems designed by Mitsubishi Electric, as well as models for data managed by enterprise information systems. The developed algorithms for exemplar learning, abrupt change detection, video highlight extraction, non-linear regression, gray-box systems identification, memory-based classification, sequential recommendation, and business process mining are among the best in their class.

Research on decision analytics combines the predictive models learned from data with large-scale optimization methods for planning and scheduling in large problem spaces. Under investigation are formalisms for sequential decision making such as factored Markov decision process models and stochastic Petri nets.

Data preprocessing also requires developments in supporting areas such as signal processing, exploratory data analysis, and software infrastructure. Data-base and data-stream management systems have been constructed using novel ideas such as software oriented architectures, web services, and business process management systems. Several innovative signal processing algorithms for dimensionality reduction and feature extraction have been developed, using non-negative matrix factorization and independent component analysis. These methods, combined with predictive and decision algorithms, will lead to a new breed of technology and systems for improved decision making based on data analysis.

Recent Research

Semi-Supervised Information Extraction from Variable-Length Web-Page Lists

Citation: Nikovski, D.; Esenther, A.; Baba, A., "Semi-Supervised Information Extraction from Variable-Length Web-Page Lists", *International Conference on Enterprise Information Systems (ICEIS)*, May 2009

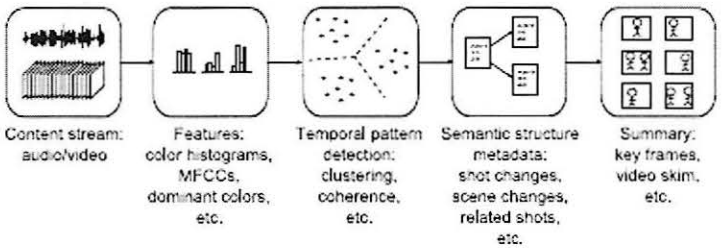
Contacts: Daniel Nikovski, Alan Esenther

We propose two methods for constructing automated programs to extract information from a class of very common web pages of high practical significance—variable-length lists of records with identical structure. Our algorithms require just a single example of the target web page in order to construct extraction rules. The first method analyzes the document object model (DOM) tree of the web page to identify repeatable structure that includes all of the specified data fields of interest. The second method provides an interactive way of discovering the list node of the DOM tree by visualizing the correspondence between portions of XPath expressions and visual elements in the web page. Both methods construct extraction rules in the form of XPath expressions, facilitating ease of deployment and integration with other information systems.

Broadcast Video Content Segmentation by Supervised Learning

Citation: Wilson, K.W.; Divakaran, A., "Broadcast Video Content Segmentation by Supervised Learning", *Multimedia Content Analysis*, ISBN: 978-0-387-76569-3, pp. 1-17, Mar 2009

Contact: Kevin Wilson

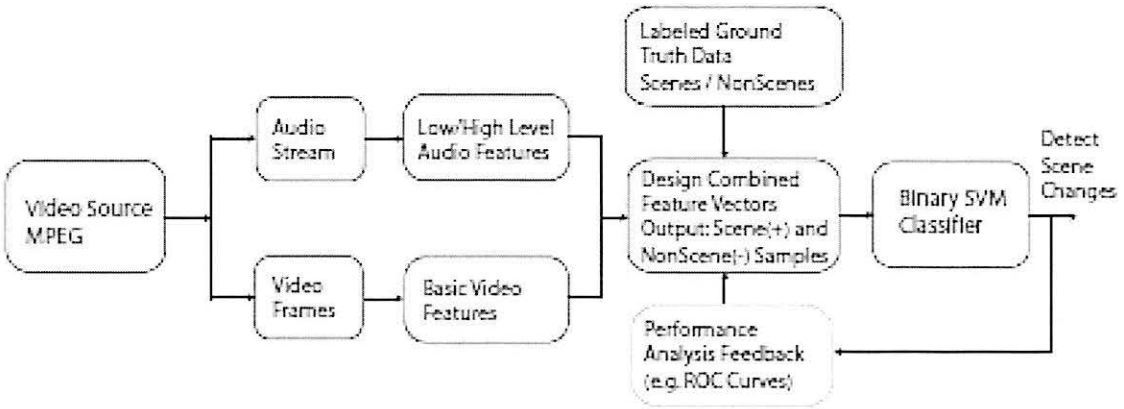


Today's viewers are presented with huge amounts of content from broadcast, cable, pay-per-view, internet streaming, and other sources. An expanding array of display devices and viewing environments further motivates the need for video summarization, rapid navigation, and management tools. However, most video summarization goals are stated in semantic terms ("the most informative summary", "the most exciting plays of the match"), while our computational tools are best at extracting simple features like audio energy and color histograms. This chapter presents our supervised learning approach to bridge this "semantic gap" by using hand-labeled examples to locate all the scene changes within content in a way that will work across a broad range of genres, including news, situation comedies, dramas, how-to shows, and more. We believe this is a useful and semantically meaningful goal that can serve as a building block in a variety of higher-level video summarization systems.

Discriminative Genre-Independent Audio-Visual Scene Change Detection

Citation: Wilson, K.W.; Divakaran, A., "Discriminative Genre-Independent Audio-Visual Scene Change Detection", *SPIE Conference on Multimedia Content Access: Algorithms and Systems III*, Vol. 7255, Jan 2009

Contact: Kevin Wilson

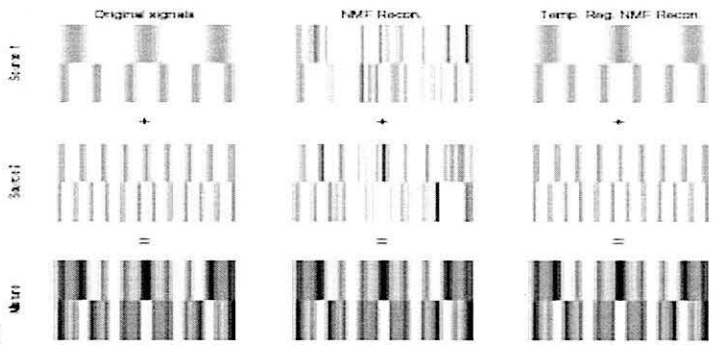


We present a technique for genre-independent scene-change detection using audio and video features in a discriminative support vector machine (SVM) framework. This work builds on our previous work by adding a video feature based on the MPEG-7 "scalable color" descriptor. Adding this feature improves our detection rate over all genres by 5% to 15% for a fixed false positive rate of 10%. We also find that the genres that benefit the most are those with which the previous audio-only was least effective.

Regularized Non-negative Matrix Factorization with Temporal Dependencies for Speech Denoising

Citation: Wilson, K. W.; Raj, B.; Smaragdis, P., "Regularized Non-negative Matrix Factorization with Temporal Dependencies for Speech Denoising", *Interspeech* , September 2008

Contact: Kevin Wilson



We present a tecchnique for denoising speech using temporally regularized nonnegative matrix factorization (NMF). In previous work, we used a regularized NMF update to impose structure within each audio frame. In this paper, we add frame-to-frame regularization across time and show that this additional regularization can also improve our speech denoising results. We evaluate our algorithm on a range of nonstationary noise types and outperform a state-of-the-art Wiener filter implementation.

Incremental Exemplar Learning Schemes for Classification on Embedded Devices

Citation: Jain, A.; Nikovski, D., "Incremental Exemplar Learning Schemes for Classification on Embedded Devices", *European Conference on Machine Learning and Principles and Practice of Knowledge Discovery in Databases (ECML PKDD)*, Sept 2008

Contacts: Ankur Jain, Daniel Nikovski

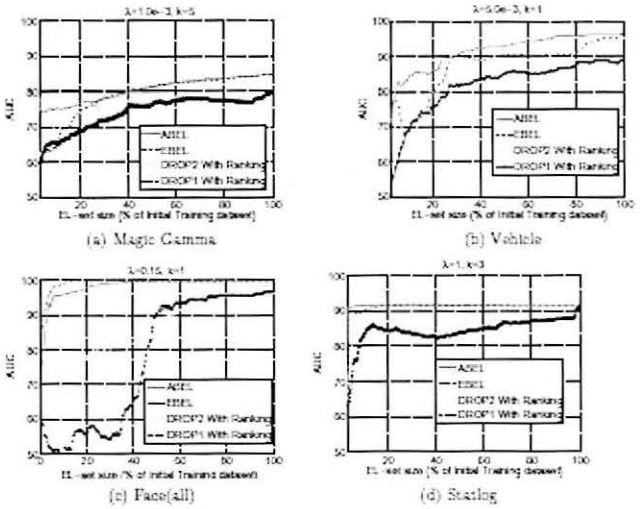


Figure 1: AUC performance against exemplar set size.

Although memory-based classifiers offer robust classification performance, their widespread use on embedded devices is hindered due to limited memory resources in an environment where data exhibits evolutionary changes which entails frequent update of the in-memory training data. A viable option for dealing with the memory constraint is to use Exemplar Learning (EL) schemes that learn a small memory set (the exemplar set) of high functional information that fits in memory. We propose two novel EL schemes, EBEL (Entropy-Based Exemplar Learning) and ABEL (AUC-Based Exemplar Learning), that overcome the short-comings of traditional EL algorithms. Our schemes efficiently incorporate new training datasets while maintaining high quality exemplar sets of any user-defined size. We present a comprehensive experimental analysis showing excellent classification-accuracy versus memory-usage tradeoffs using our proposed methods.

Imaging

The research in the Imaging group at MERL covers all aspects of extracting information from images. For instance, from a picture of a face we can calculate a numerical code for that face that allows recognizing that person again in another picture. Or we can track a moving object in video to quantify its trajectory. In some cases we can modify the actual image creation process to make subsequent information extraction more effective. For instance multiple flash exposures can be used to identify an object's edges. In other cases we can combine information from cameras with information from other sensors, for instance searching a historical database from a network of motion sensors to access stored video that documents the motion at the time and place specified.

For several years MERL has contributed to products in the security and surveillance area. Mitsubishi Electric has introduced an access control device based on the face detection and face recognition algorithms that were developed at MERL. Several other Mitsubishi Electric surveillance products use tracking algorithms that originated in MERL. Most of the object detection and tracking research heavily uses machine learning algorithms and image processing. Recently we have been getting more involved in the measurement of shape—a fundamental aspect of problems in robot vision and medical imaging. Our recent research has also pushed the boundaries of camera image forming by introducing structure in the details of the camera exposure time or aperture, allowing recovery of richer image information.

Recent Research

Face Recognition: Where we are and where to go from here

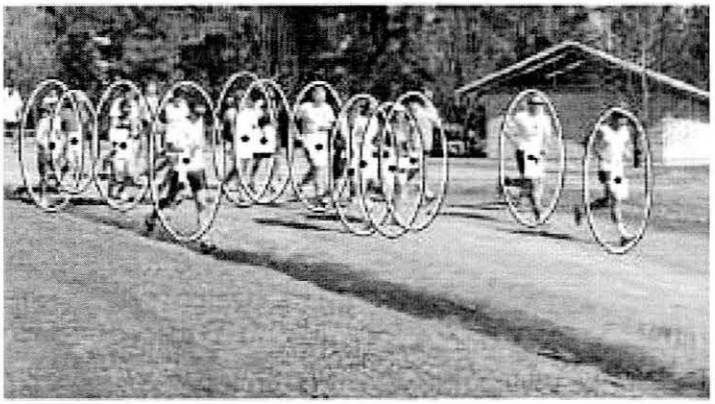
Citation: Jones, M.J., "Face Recognition: Where we are and where to go from here", *IEEJ Transactions on Electronic, Information and Systems*, Vol. 129, No. 5, pp. 770-777, January 2009
Contact: Mike Jones

Fig. 4. Examples of a face with various expressions

Face recognition has become a very active research field. Despite the existence of commercial face recognition systems, there are still important challenges for further research. The problems of variable lighting, pose, facial expression, aging, and inaccurate alignment continue to cause larger than desired error rates. This paper discusses the current state of the art in face recognition and suggests some promising directions for future research.

Pedestrian Detection via Classificaiton on Riemannian Manifolds

Citation: Tuzel, O.; Porikli, F.; Meer, P., "Pedestrian Detection via Classification on Riemannian Manifolds", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, ISSN: 0162-8828, Vol. 30, Issue 10, pp. 1713-1727, October 2008
Contacts: Oncel Tuzel, Fatih Porikli

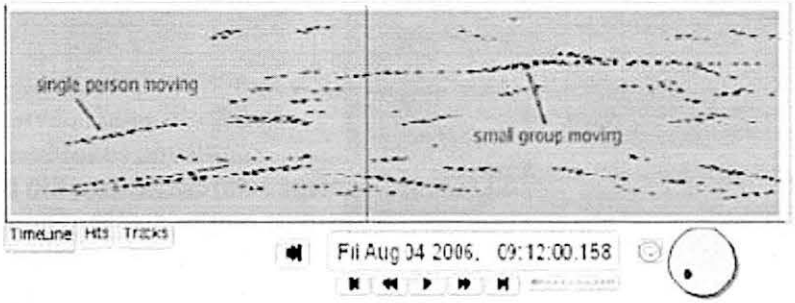


We present a new algorithm to detect pedestrians in still images utilizing covariance matrices as object descriptors. Since the descriptors do not form a vector space, well-known machine learning techniques are not well suited to learn the classifiers. The space of d-dimensional nonsingular covariance matrices can be represented as a connected Riemannian manifold. The main contribution of the paper is a novel approach for classifying points lying on a connected Riemannian manifold using the geometry of the space. The algorithm is tested on the INRIA and DaimlerChrysler pedestrian data sets where superior detection rates are observed over the previous approaches.

Ambient Intelligence as the Bridge to the Future of Pervasive Computing

Citation: Wren, C.R.; Ivanov, Y.A., "Ambient Intelligence as the Bridge to the Future of Pervasive Computing", *IEEE International Conference on Automatic Face and Festure Recognition*, September 2008

Contact: Yuri Ivanov



We survey a body of work on perceptual tools for smart buildings, built on the sensor network model, and focused on the idea that statistical methods and population dynamics can provide valuable information even in situations where detection of individual instances of behavior may be difficult. These are some of the tools that will fuel the building optimization applications to justify efforts of early adopters of smart buildings studded with pervasive technology.

Glare Aware Photography: 4D Ray Sampling for Reducing Glare Effects of Camera Lenses

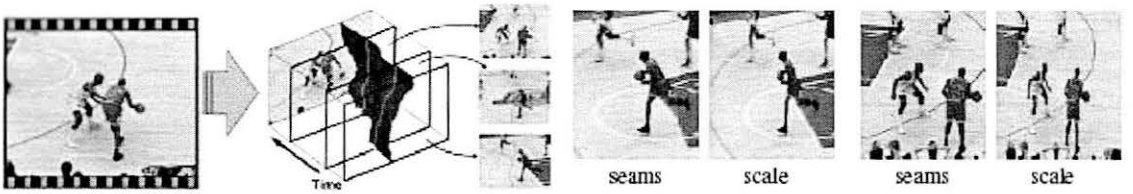
Citation: Raskar, R.; Agrawal, A.; Wilson, C.; Veeraraghavan, A., "Glare Aware Photography: 4D Ray Sampling for Reducing Glare Effects of Camera Lenses", *ACM Transactions on Graphics (TOG)*, ISSN:0730-0301, Volume 27 , Issue 3, August 2008

Contacts: Amit Agrawal, Asok Veeraraghavan

Glare arises from multiple scattering of light inside the camera's body and lens optics and reduces image contrast. While previous approaches have analyzed glare in 2D image space, we show that glare is inherently a 4D ray-space phenomenon. By statistically analyzing the ray-space inside a camera, we can classify and remove glare artifacts. In ray-space, glare behaves as high frequency noise and can be reduced by outlier rejection. Unlike light field cameras, we do not need to reversibly encode the spatial structure of the rayspace, leading to simpler designs. We explore masks for uniform and non-uniform ray sampling and show a practical solution to analyze the 4D statistics without significantly compromising image resolution. Our approach handles photography looking into the sun and photos taken without a hood, removes the effect of lens smudges and reduces loss of contrast due to camera body reflections. We show various applications in contrast enhancement and glare manipulation.

Improved Seam Carving for Video Retargeting

Citation: Rubinstein, M.; Shamir, A.; Avidan, A., "Improved Seam Carving for Video Retargeting", *ACM Transactions on Graphics (TOG)*, Vol. 27 , Issue 3, Aug 2008



Like images, video should support content aware resizing. We present video retargeting using an improved seam carving operator. Instead of removing 1D seams from 2D images we remove 2D seam manifolds from 3D space-time volumes. To achieve this we replace the dynamic programming method of seam carving with graph cuts that are suitable for 3D volumes. In the new formulation, a seam is given by a minimal cut in the graph and we show how to construct a graph such that the resulting cut is a valid seam. That is, the cut is monotonic and connected. In addition, we present a novel energy criterion that improves the visual quality of the retargeted images and videos, looking forward in time and removing seams that introduce the least amount of energy into the retargeted result. We show how to encode the improved criterion into graph cuts (for images and video) as well as dynamic programming (for images). We apply our technique to images and videos and present results of various applications.

Learning on Lie Groups for Invariant Detection and Tracking

Citation: Tuzel, O.; Porikli, F.; Meer, P., "Learning on Lie Groups for Invariant Detection and Tracking", *IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR)*, ISSN: 1063-6919, Jun 2008

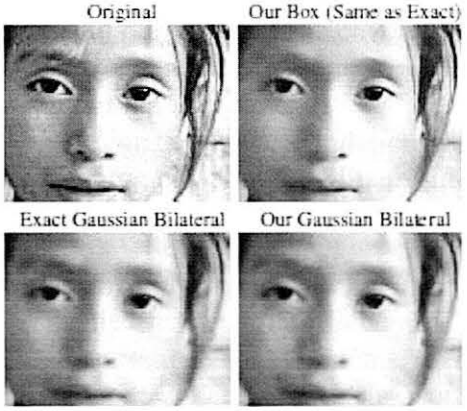
Contacts: Oncel Tuzel, Fatih Porikli

This paper presents a novel learning based tracking model combined with object detection. The existing technique proceeds by linearizing the motion, which makes an implicit Euclidean space assumption. Most of the transformations used in computer vision have a matrix Lie group structure. We learn the motion model on the Lie algebra and show that the formulation minimizes a first order approximation to the geodesic error. The learning model is extended to train a class-specific tracking function which is then integrated with an existing pose-dependent object detector to build a pose-invariant object detection algorithm. The proposed model can accurately detect objects in various poses where the size of the search space is only a fraction of that for existing object detection methods. The detection rate of the original detector is improved by more than 90% for large transformations.

Constant Time O(1) Bilateral Filtering

Citation: Porikli, F., "Constant Time O(1) Bilateral Filtering", *IEEE Computer Society Conference on Computer Vision and Pattern Recognition (CVPR)*, Jun 2008

Contacts: Fatih Porikli



This paper presents three novel methods that enable bilateral filtering in constant time O(1) without sampling. Constant time means that the computation time of the filtering remains same even if the filter size becomes very large. Our first method takes advantage of the integral histograms to avoid the redundant operations for bilateral filters with box spatial and arbitrary range kernels. For bilateral filters constructed by polynomial range and arbitrary spatial filters, our second method provides a direct formulation by using linear filters of image powers without any approximation. Lastly, we show that Gaussian range and arbitrary spatial bilateral filters can be expressed by Taylor series as linear filter decompositions without any noticeable degradation of filter response. All these methods drastically decrease the computation time by cutting it down constant times (e.g. to 0.06 seconds per 1MB image) while achieving very high PSNR's over 45dB. In addition to the computational advantages, our methods are straightforward to implement.

Mechatronics

The newly created Mechatronics group conducts research, development and generation of state-of-the-art theory and technology in the areas of mechatronics design and control, merging advanced control theory, mechanical and materials engineering, optics, signal and power electronics, physics, and thermodynamics, with the intent to expand the performance envelope of mechatronic technology. The Mechatronics group also pursues the advancement and improvement of Mitsubishi Electric's products that utilize mechtaronics and control technologies, and develops advanced technologies and tools for design, analysis, simulation and visualization of related processes. MERL researchers are collaborating closely with Mitsubishi Electric's mechatronics and control R&D facilities in Japan.

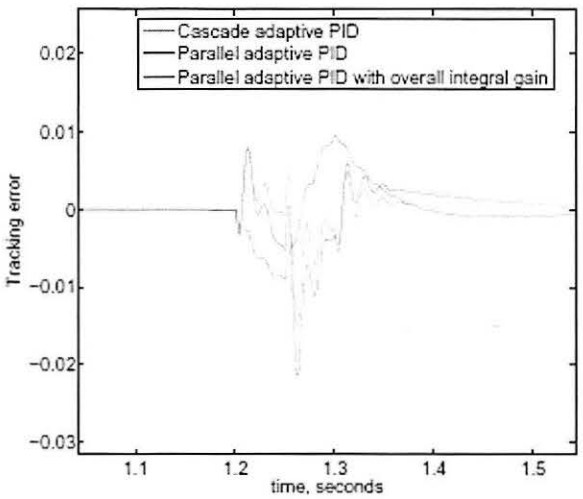
The motivations for this R&D program are twofold. First, the design and control of electromechanical devices is central to many areas of Mitsubishi Electric's business. Second, with the rapidly increasing power of embedded computation in electromechanical systems, there is the opportunity for synergy among research in mechatronics and control and MERL's existing research strengths in computer and information technology.

Recent Research

Nonlinearly Parameterized Adaptive PID Control for Parallel and Series Realizations

Citation: El Rifai, K., "Nonlinearly Parameterized Adaptive PID Control for Parallel and Series Realizations", *American Control Conference (ACC)*, June 2009

Contacts: Scott Bortoff



In this paper, a methodology for Lyapunov-based adaptive PID control for different nonlinearly-parameterized series and parallel PID realizations is presented using simple first and second order dominant plants. The corresponding designs are based on using only the tracking error, its derivative, its integral, and the current value of the adaptive gains in order to update the PID gains. The conventional independent parallel realization, which most existing adaptive designs have used, yields a linearly parameterized adaptive control problem. Whereas, other parallel as well as series realizations yield nonlinearly parameterized adaptive systems allowing for coupled adaptation of the PID gains and further design flexibility. These coupled architectures promise to yield better adaptation and learning as they reflect the inherently coupled nature of PID tuning. Case study simulations are provided to demonstrate the capabilities of the developed algorithm.

Algorithms

The Algorithms group at MERL develops solution methods for optimization problems involving very large numbers of variables. Typically these arise in inference problems involving images, video, or audio; network transport problems; coding and compression problems; or design problems. Usually these problems are characterized by very complicated probability distributions in extremely high dimensional spaces. Because classical approaches to these problems are infeasible, our results can open new business opportunities where there are no competitive technologies.

Most of the group's work revolves around graph-based optimizations and inference, where the graph is a representation of the problem constraints and a probability distribution over possible solutions. Through formal analysis we identify tractable estimation or approximation schemes. This meshes with MERL's expertise in fields and technologies such as belief propagation, machine learning, computer vision, dynamic programming, convex optimization, coding and communications theory, and signal processing.

Recent Research

Image and Video Retargetting by Darting

Citation: Brand, M., "Image and Video Retargetting by Darting", *Image Analysis and Recognition*, ISBN: 978 3 642 02610 2, Vol. 5627/2009, pp. 33-42, July 2009
Contact: Matt Brand

We consider the problem of altering an image by imperceptibly adding or removing pixels, for example, to fit a differently shaped frame with minimal loss of interesting content. We show how to construct a family of convex programs that suitably rearrange pixels while minimizing image artifacts and distortions. We call this "darting" on analogy to a tailor's darts—small edits are discreetly distributed throughout the fabric of the image.We develop a reduction to integer dynamic programming on edit trellises, yielding fast algorithms. One- and two-pass variants of the method have O(1) per-pixel complexity. Of the many edits that darting supports, five are demonstrated here: image retargetting to smaller aspect ratios; adding or moving or removing scene objects while preserving image dimensions; image expansion with gaps filled by a rudimentary form of texture synthesis; temporal video summarization by "packing" motion in time; and an extension to spatial video retargetting that avoids motion artifacts by preserving optical flow.

Multi-Stage Decoding of LDPC Codes

Citation: Wang, Y.; Yedidia, J.S.; Draper, S.C., "Multi-stage Decoding of LCPC Codes", *IEEE International Symposium on Information Theory*, June 2009 (ISIT 2009)
Contacts: Yige Wang, Jonathan Yedidia

We present a three-stage decoding strategy that combines quantized and un-quantized belief propagation (BP) decoders with a mixed-integer linear programming (MILP) decoder. Each decoding stage is activated only when the preceeding stage fails to converge to a valid codeword. The faster BP decoding stages are able to correct most errors, yielding a short average decoding time. In the rare cases when the iterative stages fail, the slower but more powerful MILP decoder used, iteratively adding binary constraints until either the maximum likelihood codeword is found or some maximum number of binary constraints has been added. Simulation results demonstrate a large improvement in the word error rate (WER) of the proposed multi-stage decoder in comparison to belief propagation. The improvement is particularly noticeable in the low crossover probability (error floor) regime. Introduction of an accelerated "active-set" version of the quantized BP decoder significantly speeds up the pace to simulate LDPC codes of length up to around 2000 down to a WER of around 10(10) on the binary symmetric channel.

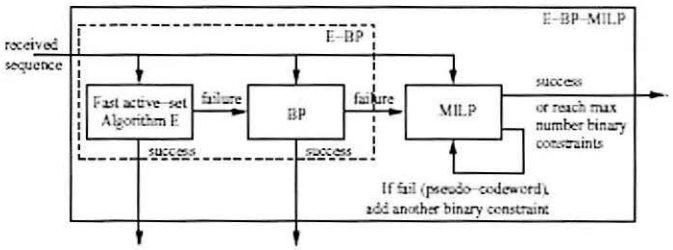


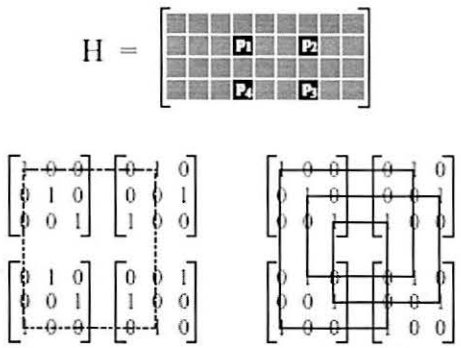
Fig. 1. Structure of an E-BP-MILP decoder.

Construction of High-Girth QC-LDPC Codes

Citation: Wang, Y.; Yedidia, J.S.; Draper, S.C., "Construction of High-Girth QC-LDPC Codes", *Turbo Coding*, September 2008

Contacts: Yige Wang, Jonathan Yedidia

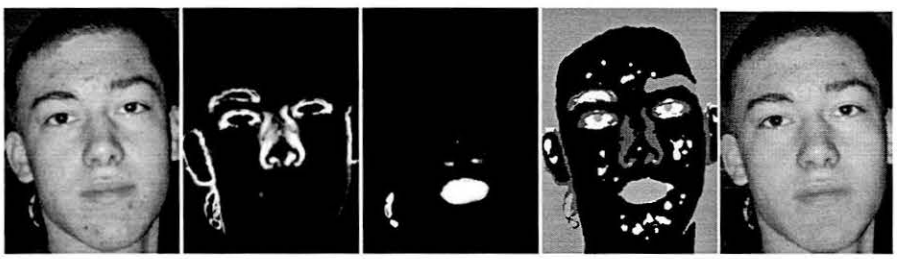
We describe a hill-climbing algorithm that constructs high-girth quasi-cyclic low-density parity check (QCLDPC) codes. Given a desired girth, the algorithm can find QCLDPC codes of shorter block-length in much less time compared with the previously proposed "guess-and-test" algorithm. An analysis is also provided to explain when guess-and-test would be expected to perform well or badly.



A Conditional Random Field for Automatic Photo Editing

Citation: Brand, M.; Pletscher, P., "A Conditional Random Field for Automatic Photo Editing," *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, ISSN 1063-6919, pp. 1-7, June 2008

Contact: Matt Brand

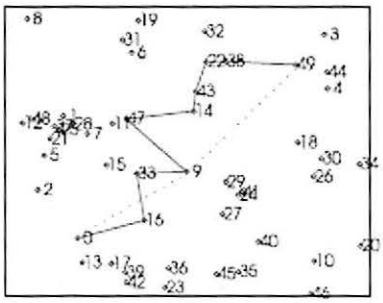

(a) input (b) shadow evidence (c) lip/gum evidence (d) most likely classes (e) output

We introduce a method for fully automatic touch-up of face images by making inferences about the structure of the scene and undesirable textures in the image. A distribution over image segmentations and labelings is computed via a conditional random field; this distribution controls the application of various local image transforms to regions in the image. Parameters governing both the labeling and transforms are jointly optimized w.r.t. a training set of before-and-after example images. One major advantage of our formulation is the ability to marginalize over all possible labeling and thus exploit all the information in the distribution; this yield better results than MAP inference. We demonstrate with a system that is trained to correct red-eye, reduce specularities, and remove acne and other blemishes from faces, showing results with test images scavenged from acne-themed internet message boards.

Routing in Cooperative Wireless Networks with Mutual-Information Accumulation

Citation: Draper, S.C.; Liu, A.; Molisch, A.F.; Yedidia, J.S., "Routing in Cooperative Wireless Networks with Mutual-Information Accumulation", *IEEE International Conference on Communications (ICC)*, ISBN: 978-1-4244-2075-9, pp. 4272-4277, May 2008

Contact: Jonathan Yedidia

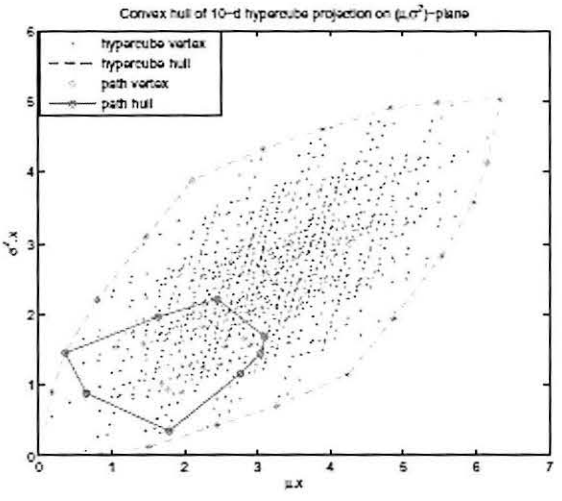


Cooperation between the nodes of wireless multihop networks can increase communication reliability, reduce energy consumption, and decrease latency. The possible improvements are even greater when nodes perform mutual-information accumulation, e.g., by using rateless codes. We investigate routing problems in such networks. Given a network, a source and a destination, our objective is to minimize end-to-end transmission delay under a sum energy constraint. We provide an algorithm that determines which nodes should participate in forwarding the message and what resources (time, energy, bandwidth) should be allocated to each. In comparison to the cooperative routings, it is observed that conventional shortest-path multihop routings incur additional delays and energy expenditures on the order of 70%. Since this initial solution is centralized, requiring full channel state information, we exploit the insights to design two distributed routing algorithms that require only local channel state information. We provide simulations showing that in the same networks the distributed algorithms find routes that are only about 2 - 5% less efficient than the centralized solution.

Stochastic Shortest Paths Via Quasi-convex Maximization

Citation: Nikolova, E.; Kelner, J.; Brand, M.; Mitzenmacher, M., "Stochastic Shortest Paths Via Quasi-convex Maximization", *ESA 2006*, ISBN:3-540-38875-3, Pp 552 - 563 , September 2006

Contact: Matt Brand

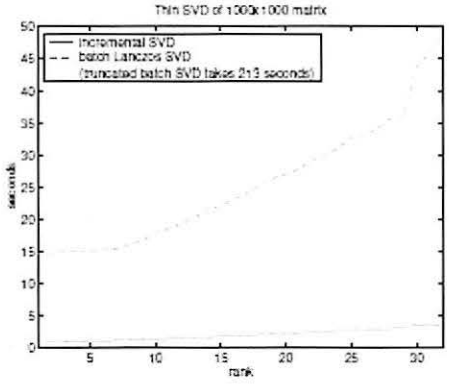


We consider the problem of finding shortest paths in a graph with independent randomly distributed edge lengths. Our goal is to maximize the probability that the path length does not exceed a given threshold value (deadline). We give a surprising exact $n^{\Theta(\log n)}$ algorithm for the case of normally distributed edge lengths, which is based on quasi-convex maximization. We then prove average and smoothed polynomial bounds for this algorithm, which also translate to average and smoothed bounds for the parametric shortest path problem, and extend to a more general non-convex optimization setting. We also consider a number other edge length distributions, giving a range of exact and approximation scheme.

Fast Low-Rank Modifications of the Thin Singular Value Decomposition

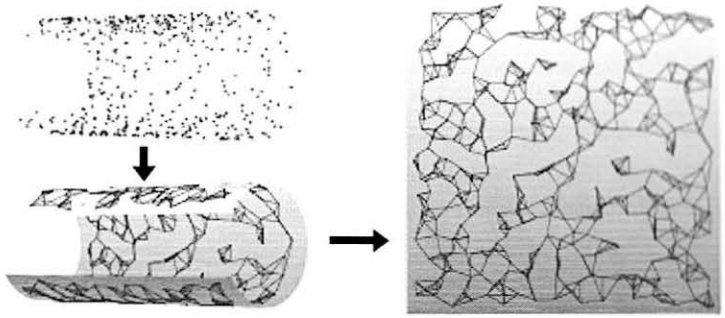
Citation: Brand, M., "Fast Low-Rank Modifications of the Thin Singular Value Decomposition," *Linear Algebra and Its Applications*, Vol. 415, Issue 1, pp. 20-30, May 2006
Contact: Matt Brand

This paper develops an identity for additive modivations of a singular value decomposition (SVD) to reflect updates, downdates, shifts, and edits of the data matrix. This sets the stage for fast and ememory-efficient sequential algorithms for tracking singular values and subspaces. In conjunction with a fast solution for the pseudo-inverse of a submatrix of an orthogonal matrix, we develop a scheme for computing a thin SVD of streaming data in a single pass with linear time complexity: A rank-r think SVD of a $p \times q$ matrix can be computed in $O(pqr)$ time for $r \leq \sqrt{\min(p,q)}$.



Nonrigid Embeddings for Dimensionality Reduction

Citation: Brand, M., "Nonrigid Embeddings for Dimensionality Reduction", *European Conference on Machine Learning (ECML)*, ISBN: 3-540-29243-8, Vol. 3720, October 2005
Contact: Matt Brand

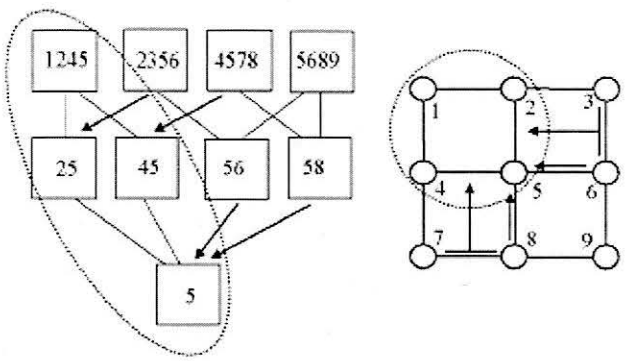


Spectral methods for embedding graphs and immersing data manifolds in low-dimensional spaces are notoriously unstable due to insufficient and/or numerically ill-conditioned constraint sets. Why show why this is endemic to spectral methods, and develop low-complexity solutions for stiffening ill-conditioned problems and regularizing ill-posed problems, with proofs of correctness. The regularization exploits sparse but complementary constraints on affine rigidity and edge lengths to obtain isometric embeddings. An implemented algorithm is fast, accurate, and industrial-strength: Experiments with problem sizes spanning four orders of magnitude show *O(N)* scaling. We demonstrate with speech data.

Understanding Belief Propagation and Its Generalizations

Citation: Yedidia, J.S.; Freeman, W.T.; Weiss, Y., "Understanding Belief Propagation and Its Generalizations", *Exploring Artificial Intelligence in the New Millennium*, ISBN 1558608117, Chap. 8, pp. 239-236, January 2003

Contact: Jonathan Yedidia



"Inference" problems arise in statistical physics, computer vision, error-correcting coding theory, and AI. We explain the principles behind the belief propagation (BP) algorithm, which is an efficient way to solve inference problems based on passing local messages. We develop a unified approach with examples, notation, and graphical models borrowed from the relevant disciplines.We explain the close connection between the BP algorithm and the Bethe approximation of statistical physics. In particular, we show that BP can only converge to a fixed point that is also a stationary point of the Bethe approximation to the free energy. This result helps explain the successes of the BP algorithm and enables connections to be made with variational approaches to approximate inference.