FORTY-FIFTH
ASILOMAR CONFERENCE ON
SIGNALS, SYSTEMS & COMPUTERS

Organized in cooperation with

NAVAL POSTGRADUATE SCHOOL
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Welcome from the General Chairman

Dr. Jim Schroeder, Harris Corporation, Melbourne, Florida

I am very pleased to welcome you to the 45th Asilomar Conference on Signals, Systems and Computers. I personally attended my first Asilomar Conference in 1988, October 31st to November 2nd; the Asilomar State Park's beautiful and relaxing venue, complemented by the intellectual stimulation provided by the conference attendees, has kept me returning year after year.

A continuing strength of Asilomar is the wide cross section of researchers who come from traditional academic institutions, including esteemed faculty and their graduate students, Federal R&D Laboratories and Corporate Research centers, enables an unmatched synergy unique to Asilomar.

This year's Sydney Parker Memorial Lecture will be presented by Prof. Jose Principe, University of Florida, Gainesville, titled, "Machine Learning in Signal Processing." Jose Principe is a Distinguished Professor of Electrical and Computer Engineering and Biomedical Engineering at the University of Florida where he teaches advanced signal processing, machine learning and artificial neural networks (ANNs) modeling. He is the BellSouth Professor and the Founder and Director of the University of Florida Computational NeuroEngineering Laboratory (CNEL) www.cnel.ufl.edu . His primary area of interest is the processing of time varying signals with adaptive neural models. The CNEL Lab has been studying signal and pattern recognition principles based on information theoretic criteria (entropy and mutual information).

The popular and successful student paper contest will be chaired this year by Dr. Oscar Gustafsson, Linkoping University, Sweden. The student finalists have been selected to present their papers to the panel judges Sunday afternoon. The top three paper winners will receive their awards at the beginning of the conference plenary session.

It is a privilege and honor to serve as this year's General Chair. I personally invite you to enjoy Asilomar to its fullest from the Plenary Talk, Student Poster Sessions, oral and poster sessions and colorful sunsets on the beach.

Jim Schroeder, Harris Corporation, May 2011

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2011 Asilomar Conference Session Schedule

Sunday Afternoon, November 6, 2011

2:00 - 7:00 pm	Registration — Merrill Hall
4:00 - 6:30 pm	Student Paper Contest — Heather
7:00 - 9:00 pm	Welcoming Dessert Reception — Merrill Hall

Monday Morning, November 7, 2010

7:30 - 9:00 am	Breakfast – Crocker Dining Hall
8:00 am - 6:00 pm	Registration
8:15 - 9:45 am	MA1a — Conference Welcome and Plenary Session
9:45 - 10:15 am	Coffee Social
10:15 am - 12:00 pm	MORNING SESSIONS
MA1b	Energy Efficient MIMO Communication
MA2b	Delay Sensitive Communication
MA3b	Graphical Models in Signal Processing I
MA4b	In-network Computation
MA5b	Medical Imaging
MA6b	Collaborative Beamforming
MA7b	Multivariate and Multimodal Analysis of Brain Signals
MA8b1	Computer Arithmetic I (Poster)
MA8b2	Physical Layer Security I (Poster)
MA8b3	Physical Layer Security II (Poster)
MA8b4	Image, Video Coding and Analysis (Poster)
MA8b5	Adaptive Systems and Spectral Estimation (Poster)
12:00 - 1:00 pm	Lunch – Crocker Dining Hall

Monday Afternoon, November 7, 2011

1:30 - 5:10 pm	AFTERNOON SESSIONS
MP1a	Interference-Alignment Techniques for Multi-Antenna Systems
MP1b	Interference Alignment for the MIMO Interference Channel
MP2a	Energy-Harvesting Wireless Networks
MP2b	Coding and Decoding
MP3a	Graphical Models in Signal Processing II
MP3b	Signal Processing and Learning in Complex Systems
MP4a	Compressive Sensing Applications in Networking
MP4b	Resource Allocation in Wireless Networks
MP5a	Advances in Bioimaging and Analysis
MP5b	Image/Video Restoration, Enhancement and Evaluation
MP6a	Tensor-based Array Signal Processing
MP6b	Compressive Sensing for Array Processing
MP7a	Processing of Physiological Signals
MP7b	Model-based Design Optimization
MP8a1	Adaptive Filtering (Poster)
MP8a2	Speech Processing, Recognition and Coding (Poster)
MP8a3	Parameter Estimation (Poster)
MP8a4	DSP Algorithms and Architectures (Poster)
MP8a5	Novel DSP Architectures (Poster)

Monday Evening, November 7, 2011

6:00 - 9:30 pm Conference Cocktail/Social — Merrill Hall
The Cocktail/Social takes the place of Monday's dinner. No charge for conference attendees or their guests

2011 Asilomar Conference Session Schedule

(continued)

Tuesday Morning, November 8, 2011

7:30 - 9:00 am Breakfast — Crocker Dining Hall
8:00 am - 5:00 pm Registration

8:15 - 12:00 PM MORNING SESSIONS

TA1a Random Matrices in Signal Processing and MIMO Communications
TA1b Biosignal Estimation and Classification
TA2a Network Coding
TA2b Relaying through Frequency Selective Channels
TA3a Advances in Compressive Sensing
TA3b Sparse Reconstruction
TA4a Next Generation Network Science
TA4b Bio-inspired Models and Algorithms for Information Processing in Complex Networks
TA5a Image and Video Retrieval
TA5b Sparse Representations with Applications to Images and Video
TA6a Waveform Design and MIMO Radar
TA6b Network Beamforming and Relaying via Multiple Antennas
TA7 Architectures for Wireless Communications
TA8a1 Signal Processing Methods for Representation, Analysis, and Control of Biological Systems (Poster)
TA8a2 Receiver Design and Optimization (Poster)
TA8a3 Communications System Design (Poster)
TA8a4 Applications of Array Processing (Poster)
TA8b1 Multiple Antennas in Multi-User Systems and Networks (Poster)
TA8b2 Cooperative and Cognitive Transmission in Multi-Antenna Systems (Poster)
TA8b3 Adaptive Sensing (Poster)

12:00 - 1:00 PM Lunch – Crocker Dining Hall

Tuesday Afternoon, November 8, 2011

1:30 - 5:10 PM AFTERNOON SESSIONS

TP1a Resource Allocation in Multi-Antenna Systems
TP1b Interference Management
TP2a Cognitive Radio I
TP2b Cognitive Radio II
TP3a Multi-dimensional Compressive Inference
TP3b Advances in Adaptive and Distributed Filtering
TP4a Communication Management in Robot Networks
TP4b Distributed Storage Systems
TP5 Compressive Sensing for Radar
TP6a Source Localization
TP6b Array Processing for Satellite Communications
TP7a Adaptive and Evolvable Architectures
TP7b Computer Arithmetic II
TP8a1 Techniques for Space-Time Signal Processing (Poster)
TP8a2 Statistical and Array Signal Processing for Biomedical Applications (Poster)
TP8a3 Sensor Networks (Poster)
TP8a4 Wireless Networks (Poster)
TP8b1 Machine-Learning-Based Statistical Signal Processing (Poster)
TP8b2 Network Information Theory (Poster)

Tuesday Evening, November 8, 2011

No conference planned event, please enjoy the Monterey Peninsula.

2011 Asilomar Conference Session Schedule

(continued)

Wednesday Morning, November 9, 2011

7:30 - 9:00 am	Breakfast — Crocker Dining Hall
8:00 am - 12:00 pm	Registration — Copyright forms must be turned in before the registration closes at 12:00 noon.
8:15 am - 12:00 pm	MORNING SESSIONS
WA1a	Channel Estimation for Multi-Antenna Systems
WA1b	MIMO Radar and SAR
WA2a	OFDM
WA2b	Beamforming
WA3a	Information Theoretic Signal Processing
WA3b	Compressive Imaging and Detection
WA4a	Cooperation & Relays
WA4b	Multiuser Information Theory
WA5a	Signal Theory and Image Representation
WA5b	Biometrics
WA6a	Computational Aspects in Array Processing
WA6b	Source Separation
WA7a	Multi-core/GPU Implementation
WA7b	Reconfigurable Architectures, Algorithms and Applications
12:00 - 1:00 pm	Lunch — Meal tickets may be purchased at registration desk. This meal is not included in the registration.

Student Paper Contest

Heather Hall - Sunday, November 6, 2011, 4:30 - 6:30 PM

"Spectrum Leasing via Cooperative Opportunistic Routing in Distributed Ad Hoc Networks: Optimal and Heuristic Policies"

Cristiano Tapparello, Davide Chiarotto, Michele Rossi, University of Padova; Osvaldo Simeone, New Jersey Institute of Technology; Michele Zorzi, University of Padova

"Correcting Erasure Bursts with Minimum Decoding Delay"

Zhi Li, Stanford University; Ashish Khisti, University or Toronto; Bernd Girod, Stanford University

"Asymptotic Analysis of Double-Scattering Channels"

Jakob Hoydis, Romain Couillet, and Merouane Debbah, SUPELEC

"Mutual Information Distribution of Interference-Limited MIMO: A Joint Coulomb Fluid and Painleve Based Approach"

Shang Li, Hong Koong University of Science and Technology; Yang Chen, Imperial College London; Matthew McKay, Hong Kong University of Science and Technology

"MSE-Optimal Power Allocation in Wireless Sensor Networks for Field Reconstruction Based on Shift-Invariant Spaces"

Günter Reise, Vienna University of Technology; Javier Matamoros and Carles Antôn-Haro, CTTC; Gerald Matz, Vienna University of Technology

"On the Limits of Sequential Testing in High Dimensions"

Matthew Malloy and Robert Nowak, University of Wisconsin

"Non-Uniform Linear Arrays for Improved Identifability in Cumulant Based DOA Estimation"

Piya Pal and P.P. Vaidyanathan, California Institute of Technology

"Maximum Likelihood Time Delay Estimation for CDMA Direct Spread Multipath Transmissions Using Importance Sampling"

Ahmed Masmoudi, Faouzi Bellili, and Sofiene Affes, INRS-EMT

"Haplotype Inference Based on Sparse Dictionary Selection"

G.H. Jajamovich and X. Wang, Columbia University

"A High-Performance Area-Efficient AES Encipher on a Many-core Platform"

Bin Liu and Bevan Baas, University of California, Davis

"Learning Dictionaries for Local Sparse Coding in Image Classification"

Jayaraman J. Thiagarajan and Andreas Spanias, Arizona State University

Coffee breaks will be at 9:55 AM and 3:10 PM. (Except Monday morning when refreshments will be served outside Chapel from 9:45–10:15 AM)

Monday, November 7, 2011

CONFERENCE OPENING AND PLENARY SESSION 8:15 – 9:45 AM, LOCATED IN CHAPEL

1. Welcome from the General Chairperson:

Dr. James Schroeder
Harris Government Communication Systems

2. Session MA1a Distinguished Lecture for the 2011 Asilomar Conference

Machine Learning in Signal Processing

Prof. Jose C. Principe
Distinguished Professor of Electrical Engineering
University of Florida

Abstract
This talk describes our efforts to go beyond the second order moment assumption still prevalent in optimal signal processing. We show how the second norm of the PDF can be estimated directly from data avoiding an explicit PDF estimation step. The link between PDF moments, information theory and Reproducing Kernel Hilbert spaces will be established. Applications to adaptive systems with entropic cost functions will be demonstrated. A generalized correlation function called correntopy will be defined and its applications in signal processing will be outlined. Correntopy leads to new measures of similarity, to a new definition of dependence subspaces and to new tests for causality.

Biography
Jose C. Principe (M'83-SM'90-F'00) is a Distinguished Professor of Electrical and Computer Engineering and Biomedical Engineering at the University of Florida where he teaches advanced signal processing, machine learning and artificial neural networks (ANNs) modeling. He is BellSouth Professor and the Founder and Director of the University of Florida Computational NeuroEngineering Laboratory (CNEL) www.cnel.ufl.edu. His primary area of interest is processing of time varying signals with adaptive neural models. The CNEL Lab has been studying signal and pattern recognition principles based on information theoretic criteria (entropy and mutual information).

Dr. Principe is an IEEE Fellow. He was the past Chair of the Technical Committee on Neural Networks of the IEEE Signal Processing Society, Past-President of the International Neural Network Society, and Past-Editor in Chief of the IEEE Transactions on Biomedical Engineering. He is a member of the Advisory Board of the University of Florida Brain Institute. Dr. Principe has more than 500 publications. He directed 62 Ph.D. dissertations and 65 Master theses. He wrote in 2000 an interactive electronic book entitled "Neural and Adaptive Systems" published by John Wiley and Sons and more recently co-authored several books on "Brain Machine Interface Engineering" Morgan and Claypool, "Information Theoretic Learning", Springer, and "Kernel Adaptive Filtering", Wiley.

Program of 2011
Asilomar Conference
on
Signals, Systems, and Computers

Technical Program Chairman
Prof. Robert W. Heath, Jr.
The University of Texas at Austin

Session: MAb1 – Energy Efficient MIMO Communication

Chair: ***Chan-Byoung Chae,*** *Yonsei University, S. Korea*

MA1b-1 10:15 AM

Optimal Transmission Policies over Vector Gaussian Broadcast Channels with Energy Harvesting Transmitters

Omur Ozel, University of Maryland; Jing Yang, University of Wisconsin-Madison; Sennur Ulukus, University of Maryland

We consider communication over vector Gaussian channels (parallel channels and MIMO channels) with an energy harvesting transmitter for point-to-point and broadcast scenarios. Energy required for communication arrives (is harvested) at the transmitter over the course of communication and is saved in a battery to be used in data transmissions. Based on a deterministic energy arrival model, we develop the optimal offline scheduling policy.

MA1b-2 10:40 AM

Throughput and Energy Consumption of a Random Network with Energy Harvesters

Kaibin Huang, Yonsei University

A promising approach for achieving a lasting life of a wireless network is to equip each node with an energy harvester. In this paper, the network throughput is analyzed as a function of the average amount and the burstiness of harvested energy. Specifically, the energy harvested by a node is modeled as a Poisson arrival process with a random energy amount per arrival and the network nodes are modeled as a Poisson point process on the horizontal plane. The application of marking theorem transforms the network into a 3D effective Poisson point process distributed in the product space of the 2D plane and the time axis. Based on this effective process, the relation between the network throughput and the average harvested energy is derived and its dependence on the burstiness of the energy process is characterized.

MA1b-3 11:05 AM

Large-Scale Antenna Systems for Wireless Energy Efficiency

Thomas Marzetta, Bell Laboratories, Alcatel-Lucent

Large-Scale Antenna Systems (LSAS) is a fundamentally new approach to MIMO wireless communications which provides both greater energy efficiency and higher spectral efficiency. An array comprising hundreds or even thousands of antennas transmits simultaneous generalized beams of message-bearing symbols to a much smaller number of autonomous terminals. The necessary channel-state information is obtained from reverse-link pilot sequences combined with time-division duplex reciprocity. Operating with a large excess of antennas compared with terminals is both a natural condition and a desirable condition: energy efficiency is proportional to the number of antennas irrespective of the noisiness of the channel estimates, spatial multiplexing improves both energy efficiency and spectral efficiency, and LSAS lends itself to a decentralized architecture where the signal processing burden grows only linearly with the number of antennas. The mobility of the terminals and the accompanying finite-duration coherence time of the channel limits the number of terminals who can receive simultaneous service. Inter-cell interference due to pilot contamination is the ultimate limitation on performance.

MA1b-4 11:30 AM

Energy-Efficient Training for Antenna Selection in Time-Varying Channels

Vinod Kristem, Broadcom Corporation; Neelesh B. Mehta, Indian Institute of Science; Andreas Molisch, University of Southern California

Training for antenna selection (AS) differs from that for conventional multiple antenna systems because of the use of limited hardware that AS facilitates. We analyze and optimize the performance of a novel energy-efficient training method uniquely tailored for receive AS. In it, the transmitter deliberately sends an extra pilot that leads to accurate channel estimates for the selected antenna that actually receives data. For time-varying channels, we propose a novel selection rule and prove that it minimizes the symbol error probability (SEP). We also derive closed-form expressions for the SEP of MPSK, and show that the considered training method is significantly more energy-efficient than the conventional AS training method.

Track A. Communications Systems

Session: MAb2 – Delay Sensitive Communication

Chair: ***Ashish Khisti,*** *University of Toronto*

MA2b-1 10:15 AM

Speeding Multicast by Acknowledgment Reduction Technique (SMART)

Arman Rezaee, Linda Zeger, Muriel Medard, Massachusetts Institute of Technology

We present a novel feedback protocol for wireless broadcast networks. We consider transmission of packets from a single source to many receivers over a single-hop broadcast erasure channel with two heterogeneous channels. Our method uses a predictive model to minimize feedback and duplicate data transmissions by the source. The proposed protocol enables all receivers to request their desired number of retransmissions within a single time slot. We demonstrate the favorable scalability of our technique. We also show the robustness of this scheme to uncertainty in the channels, the number of receiving nodes, packet erasure probabilities, and to partial loss of feedback. Furthermore, SMART is shown to perform nearly as well as an omniscient transmitter that requires no feedback.

MA2b-2 10:40 AM

Spatially-Aware Adaptive Error Correcting Codes for Flash Memory

Ryan Gabrys, Lara Dolecek, University of California, Los Angeles

A simple code construction is given which corrects all asymmetric errors that occur within a pairwise bounded distance of each other. This construction is then extended to include an adaptive component that, depending on the observed behavior of the memory device, changes the assumed direction of the asymmetry. Results of this type are of particular interest to emerging flash memory technologies.

MA2b-3 11:05 AM

Correcting Erasure Bursts with Minimum Decoding Delay

Zhi Li, Stanford University; Ashish Khisti, University of Toronto; Bernd Girod, Stanford University

Erasure correcting codes are widely used in upper layers of packet-switched networks, where the packet erasures often exhibt bursty patterns. The conventional wisdom to deal with bursty erasures is to apply block interleaving to break down the bursty patterns prior to error correcting coding, or use long-block Reed-Solomon codes. We show that they unnecessarily lead to sub-optimal decoding delay. In this work, with the problem model of multiple erasure bursts present in a coding block, we study the fundamental tradeoff among the rate, decoding delay and burst correction performance of erasure correcting codes. Focusing on a class of codes achieving the Singleton bound, we show that the lowest delay to recover any individual symbol not only depends on how many bursts are present in a coding block, but also on whether the source symbols are encoded causally or non-causally. We also describe a few practical linear code constructions that achieve the performance limit discussed.

MA2b-4 11:30 AM

Code Length and Rate Selection for Delay Sensitive Bursty Traffic

Tara Javidi, University of California, San Diego

Data transmission over a noisy channel is considered when the arrival of data is bursty and is subject to a delay deadline. An exponential decay of the probability of delay violation with respect to a large delay deadline is obtained. When considered in conjunction with a channel, the first natural consequence of this result is a separation principle: a separated scheme of buffering traffic and blockcoding transmissions achieves arbitrarily high reliability for an asymptotically large delay budget. In contrast, when the delay constraint, hence block lengths, is finite, the separation fails to hold. An investigation of the non-asymptotic characterization of error as suggested by Poliyanksy et. al. allows for a characterization of queue length dependent coding gain.

Track D. Signal Processing and Adaptive Systems

Session: MAb3 – Graphical Models in Signal Processing I

Chair: ***Mohsen Bayati,*** *Stanford University*

MA3b-1 **10:15 AM**

Stochastic Belief Propagation: A Low-Complexity Message-Passing Algorithm with Guarantees

Nima Noorshams, Martin Wainwright, University of California, Berkeley

We propose a novel method to reduce the complexity of the sum-product algorithm (also known as belief propagation). Given a pairwise Markov random field with discrete variables taking N states, standard belief propagation requires $\mathcal{O}(N^2)$ summations and/or multiplications per iteration. Without assuming special structure of the potentials, stochastic belief propagation (SBP) reduces the number of operations to $\mathcal{O}(N)$. As its name suggests, SBP is a stochastic version of the belief propagation algorithm, where each node only passes randomly selected partial information to its neighbors at every round. We provide a number of theoretical guarantees on the SBP algorithm, including almost sure convergence, non-asymptotic bounds on the mean-squared error, and as well as high probability bounds on the actual error in each round.

MA3b-2 **10:40 AM**

Reweighted Linear Programming for Inference and Decoding

Amin Khajehnejad, Alexandros G. Dimakis, Babak Hassibi, University of Southern California

We build on the LP decoding algorithm of Feldman et al. and introduce a post-processing step that solves a second linear program that reweights the ob jective function based on the outcome of the original LP decoder output. Our analysis shows that for some LDPC ensembles we can improve the provable threshold guarantees compared to standard LP decoding. We also show significant empirical performance gains for improving the performance of belief propagation and the related LP relaxation for several inference problems.

MA3b-3 **11:05 AM**

Message-Passing on Dense Graphs and Applications in Statistical Learning

Mohsen Bayati, Andrea Montanari, Stanford University

Recently, Donoho, Maleki and Montanari introduced approximate message passing (AMP) as an extremely effective algorithm for reconstructing high dimensional sparse signals from a small number of observations. They also showed (through extensive numerical experiments) that dynamics of AMP is accurately tracked by a simple one-dimensional iteration termed “state evolution”. We provide a rigorous foundation to state evolution and prove that it holds asymptotically in the large system limit for random matrices. Our techniques also provide a new approach for the analysis of message-passing algorithms on dense graphs.

MA3b-4 **11:30 AM**

Robust Belief Propagation

Morteza Ibrahimi, Adel Javanmard, Yashodhan Kanoria, Andrea Montanari, Stanford University

In inference algorithms, it is typically assumed that the graphical model is known exactly. On the other hand in practical applications, a graphical model is often learned from data and as such, subject to statistical and systematic errors. Inference algorithms can be fragile to errors in the model estimations (which are unavoidable for a finite training). We will discuss an inference algorithm that presents ideal robustness properties with respect to such errors.

Track C. Networks

Session: MAb4 – In-network Computation

Chair: ***Osvaldo Simeone,*** *New Jersey Institute of Technology*

MA4b-1 **10:15 AM**

Network Optimization with Heuristic Rational Agents

Ceyhun Eksin, Alejandro Ribeiro, University of Pennsylvania

We consider a distributed approach to an unconstrained network optimization problem where agents are heuristic rational. Agent’s heuristic algorithm is based on a coordinate descent algorithm where each agent becomes active randomly over time and descends with respect to its value based on self cost function and local information. Agent’s descent is subject to non-diminishing

noise i.e. it is on the average optimal through out time. For this setup, we show that the minimum cost value obtained by the sum of cost functions of each agent converges to near optimality almost surely where optimal value is defined as the minimum of the sum of cost function of each agent. Furthermore, we show that the excursions from near optimality is exponentially bounded.

MA4b-2 **10:40 AM**

A Coordination-Free Distributed Algorithm for Simple Assignment Problems Using Randomized Actions

Usman A. Khan, Tufts University; Soummya Kar, Carnegie Mellon University

In this paper, we present a distributed algorithm for simple assignment problems in multi-agent systems without the presence of a central or a local coordinator. In a simple assignment problem, a unique task is to be assigned to each agent assuming that the cost of each assignment is identical. We assume that the communication among the agents is restricted over a sparse network, i.e., no agent can communicate to all of the other agents in the network. We propose a coordination-free, memoryless, distributed algorithm that is based on inter-agent information exchange via a gossip (type) communication protocol. Each agent randomly picks a task and then either swaps its task with a randomly chosen neighbor from its neighborhood (if they have different tasks) or one of them randomly picks a new task (if they have the same task). We first consider the case when the agents have no memory such that they do not have information regarding their task and neighbor history. We then present a modification when the agents possess memory. Finally, we show that both schemes converge to the set of acceptable configurations.

MA4b-3 **11:05 AM**

Distributed Estimation of the Maximum Value over a Wireless Sensor Network

Franck Iutzeler, Jérémie Jakubowicz, Institut Telecom, Telecom ParisTech, CNRS LTCI; Walid Hachem, CNRS-Telecom ParisTech; Philippe Ciblat, Institut Telecom, Telecom ParisTech, CNRS LTCI

This paper analyzes two algorithms for the maximum value estimation over a Wireless Sensor Network: the Random Gossip relying on pairwise exchanges between the nodes, and the Broadcast in which each sensor sends its value to all its neighbors. We prove the convergence of these algorithms, and we provide tight bounds for their convergence speed.

MA4b-4 **11:30 AM**

Collaborative Sequential-Based Detection in Wireless Sensor Networks

Sabina Zejnilovic, Carnegie Mellon University; Joao Pedro Gomes, Instituto Superior Tecnico; Bruno Sinopoli, Carnegie Mellon University

Due to limited power resources, energy efficiency is an important aspect of detection using wireless sensor networks. We propose a collaborative detection scheme, based on sequential hypotheses testing, where a randomly chosen node may initiate a collaboration, collecting observations from neighboring nodes to test the hypotheses. Our simulation results show that for large networks and high SNR, the proposed scheme leads to lower communication cost and similar performance when compared to standard detection, where all the observations are collected in a fusion node. We also present how energy efficiency of the scheme evolves as a function of the network structure.

Track F. Biomedical Signal and Image Processing

Session: MAb5 – Medical Imaging

Chair: ***Ge Yang,*** *Carnegie Melon University*

MA5b-1 **10:15 AM**

Calibrationless Parallel MRI Using ORACLE (Overlapping Low-Rank Approximations for Coil Image Estimation)

Joshua Trzasko, Armando Manduca, Mayo Clinic

“Auto-calibrated” coil-by-coil reconstruction methods for parallel MRI provide a robust mechanism for accelerating MRI acquisitions. However, most such strategies require explicit formation of an inter-coil correlation operator, which means approximation error is unavoidably propagated into the reconstructed images. To circumvent this problem, Lustig et al. [1] proposed a novel strategy for coil-by-coil reconstruction of phased-array MRI data based on Fourier-domain low-rank matrix completion. In this work, we demonstrate that calibration-free parallel MRI reconstruction can also be achieved using image-domain rank constraints. By imposing rank constraints outside of the sampling domain, this alternative construction may be advantageous when considering generalized signal models, non-Cartesian acquisitions, or auxiliary image penalties.

MA5b-2 **10:40 AM**

Signal Modeling and the Cramér-Rao Bound for Absolute Magnetic Resonance Thermometry: Feasibility in Fat Tissue

Marcus Björk, Johan Berglund, Joel Kullberg, Petre Stoica, Uppsala University

Magnetic Resonance Imaging (MRI) of tissues with both fat and water resonances allows for temperature mapping through parametric modeling. The goals of this paper is to determine feasibility of absolute temperature mapping in fat tissue by examining identifiability conditions and analyzing the obtainable performance by computing the Cram´er-Rao bound (CRB) of the temperature estimates. It is showed that a high SNR is needed for practical use on a 1.5 T scanner due to the low water content. Higher field strengths can improve the bound significantly. To further reduce the variance, model simplifications can be made, at the cost of a possible bias induced by modeling errors.

MA5b-3 **11:05 AM**

Level Estimation for Sparse Reconstruction in Discrete Tomography

Yenting Lin, Antonio Ortega, Alexandros G. Dimakis, University of Southern California

In discrete tomography (DT), the goal is to reconstruct an unknown image which is assumed to have few distinct pixel level intensities from projection data. Such images arise in tomography problems where very high contrast is expected, e.g., in angiography medical imaging or electron tomography. A common assumption for DT is that the set of possible intensity levels is known in advance. However, determining the prescribed intensity levels is a difficult problem, coupled with measurement calibration and the prior knowledge of image. We introduce an unsupervised DT algorithm that jointly reconstructs the image and estimates the unknown intensity levels. Our algorithm alternates between (i) an l1 sparse recovery step with a reweighed cost function that pushes the reconstructed values close to the estimated intensities, and (ii) an estimation step for the most likely intensity levels. We experimentally demonstrate that the proposed algorithm successfully estimates the unknown levels and leads to high quality reconstruction of phantom images.

MA5b-4 **11:30 AM**

Multimodal Image Registration by Consistency of Saliency Map

Hiroyuki Takeda, University of Michigan

We propose a mutlimodal registration method by consistency of saliency maps of images to be aligned. Our method is straightforward; we first compute saliency maps, and then estimate displacements between the images with assuming that the saliency is consistent. Unlike other registration methods based on mutual information (MI), which is commonly used in medical imaging, the cost function of our method is as simple as optical flow. Hence, our approach is computationally efficient and no complex optimization algorithm is necessary. Experiments show that the accuracy of our registration method is comparable or superior to the MI-based approach.

Track E. Array Signal Processing

Session: MAb6 – Collaborative Beamforming

Chair: ***Sofiène Affes,*** *INRS-EMT, Université du Québec*

MA6b-1 **10:15 AM**

DSP-Centric Algorithms for Distributed Transmit Beamforming

Upamanyu Madhow, University of California, Santa Barbara; Raghu Mudumbai, University of Iowa; D. R. Brown, Worcester Polytechnic Institute; Patrick Bidigare, Raytheon BBN Technologies

Abstract: Distributed transmit beamforming is a means of increasing range and power efficiency via local collaboration among neighboring nodes in order to transmit a common message to a remote destination. While its basic feasibility has been established by recent analyses and prototypes, transitioning this concept to applications requires the development of protocols and architectures which can be implemented efficiently using digital signal processing (DSP). In this paper, we describe DSP-centric algorithms and their performance limits, and report on experimental results from acoustic and software radio testbeds.

MA6b-2 **10:40 AM**

Power Control for Collaborative Beamforming in Wireless Sensor Networks

Mohammed Ahmed, Sergiy Vorobyov, University of Alberta

Energy-efficient communication in wireless sensor networks (WSNs) is addressed in the physical layer by implementing collaborative beamforming (CB). CB achieves directional gain and at the same time distributes the corresponding energy consumption over the collaborative sensor nodes. However, sensor nodes in practice may have different energy budgets assigned

to CB transmission. Thus, equal power CB can deplete energy from sensor nodes with smaller energy budget faster than the rest of sensor nodes. In this paper, CB with power control is developed to prolong the lifetime of a cluster of collaborative sensor nodes by balancing the sensor node lifetimes. A novel strategy is proposed to utilize the residual energy information (REI) available at each sensor node. Power control adjusts the energy consumption rate at each sensor node while achieving the required average signal-to-noise ratio (SNR) at the destination. Simulation results show that CB with power control outperforms equal power CB in terms of prolonging the lifetime of a cluster of collaborative nodes.

MA6b-3 **11:05 AM**

Testing Zero-Feedback Distributed Beamforming with a Low-Cost SDR Testbed

George Sklivanitis, Aggelos Bletsas, Technical University of Crete

Collaborative beamforming from distributed wireless transmitters has been envisioned as a means for range extension/ connectivity enhancement if the signals transmitted from distributed terminals constructively add (i.e. in phase) at the destination receiver. The research community has mainly relied on feedback schemes from the final receiver towards the distributed transmitters, either in the form of pilot signals or explicit messages that coordinate the distributed transmissions and alleviate, to an extent, the frequency and time synchronization problems. This work assumes zero-feedback from destination towards the distributed transmitters, in sharp contrast to prior art. The frequency offsets among the distributed transmitters, typically undesired in classic beamforming schemes, are turned into an advantage and offer beamforming gains through signal alignment, i.e. when the transmitted signal-phasors align in time. The idea is validated in a custom, low-cost testbed, consisting of three embedded transmitters with highly inaccurate, internal oscillators and a software-defined radio (SDR) receiver. This collaborative beamforming demonstration, perhaps the first of its kind on zero-feedback from the final destination, could potentially spark interest on relevant critical applications with ultra low-complexity portable radios.

MA6b-4 **11:30 AM**

Distributed Cooperative Jamming for Improving Physical Layer Security

Yupeng Liu, Athina Petropulu, Rutgers University; H. Vincent Poor, Princeton University

Recent research has shown that appropriate splitting of transmit power between a data bearing signal and an artificial noise component can improve the secrecy rate of multi-input multi-output (MIMO) communications systems in the presence of eavesdroppers. The purpose of the artificial noise is to confound eavesdroppers. However, this idea requires that the source be equipped with multiple antennas, which may not be always practical due to size limitations or hardware cost concerns. This paper proposes the use of multiple single antenna nodes to deliver messages to a legitimate destination in a secure fashion. Each source node has access to the legitimate data and transmits a weighted sum of data signal and artificial noise. The goal is to maximize the interference at the eavesdroppers while maintaining a minimal signal-to-interference-plus-noise (SINR) requirement at the legitimate destination, under individual power constraint of each source node. The optimal power allocation and weight design for the data bearing signal and artificial noise of each node are investigated.

Track F. Biomedical Signal and Image Processing

Session: MAb7 – Multivariate and Multimodal Analysis of Brain Signals

Co-Chairs: ***Justin Dauwels,*** *Nanyang Technological University* ***and Deniz Erdogmus,*** *Northeastern University*

MA7b-1 **10:15 AM**

Sparse Common Spatial Patterns with Recursive Weight Elimination

Fikri Goksu, Nuri F. Ince, University of Minnesota

The past decade has shown the importance of adapting spatial patterns of neural activity while decoding it in a Brain Machine Interface (BMI) framework. The common spatial patterns (CSP) algorithm tackles this problem as feature extractor in binary BMI setups in which a number of spatial projections are computed while maximizing the variance of one class and minimizing of the other. Recent advances in data acquisition systems and sensor design now make recording the neural activity of the brain with dense electrode grids a possibility. However, high density recordings also pose new challenges such as over fitting to data as the number of recording channels increases dramatically compared to the number of training trials. In this study, we tackle this problem by constructing a sparse CSP algorithm through recursive weight elimination (CSP RWE), in which the spatial projections are computed using a subset of the recording channels. The sparse projections are expected to yield increased robustness and eliminate overfitting. We show promising initial results towards the classification of multichannel electrocortigram (ECoG) data with CSP RWE for a BMI.

MA7b-2 **10:40 AM**

Identifying Multivariate EEG Synchronization Networks through Multiple Subject Community Detection

Marcos Bolanos, Ali Yener Mutlu, Michigan State University; Edward Bernat, Florida State University; Selin Aviyente, Michigan State University

With the advance of neuroimaging technology, it is now possible to record neural activity with high temporal and spatial localization. A major challenge that remains with these multiple subject, multichannel recordings is how to infer the underlying functional networks across brain sites and multiple subjects. In this paper, we introduce an approach to quantify multivariate synchronization across multiple subjects. First, we employ a recently introduced dynamic measure of phase synchrony to quantify the bivariate relationships among neuronal populations. We then introduce a new hierarchical clustering approach to identify neuronal clusters across multiple subjects. Finally, we apply the proposed approach to a study of cognitive control involving the error-related negativity (ERN).

MA7b-3 **11:05 AM**

Frequency Constrained ShifCP Modeling of Neuroimaging Data

Morten Mørup, Technical University of Denmark

The shift invariant multilinear model based on the CandeComp/PARAFAC (CP) model denoted ShiftCP has turned useful for modeling latency changes in trial based neuroimaging data. However, for Neuroimaging data such as EEG prominent activity such as alpha oscillations drive most of the signal and as such also the extracted temporal dynamics of the ShiftCP components. To control the frequency parts of the signals modeled by ShiftCP it is useful to constrain the model in the frequency domain, thus we form a frequency constrained shiftCP model and demonstrate its success in identifying evoked and induced activity in EEG data.

MA7b-4 **11:30 AM**

Context Information Significantly Improves Brain Computer Interface Performance - A Case Study on Text Entry Using a Language Model Assisted BCI

Umut Orhan, Northeastern University; Kenneth E. Hild II, Oregon Health and Science University; Deniz Erdogmus, Northeastern University; Brian Roark, Barry Oken, Melanie Fried-Oken, Oregon Health and Science University

We present recent results on the design of the RSVP Keyboard - a brain computer interface (BCI) for expressive language generation for functionally locked-in individuals using rapid serial visual presentation of letters or other symbols such as icons. The proposed BCI design tightly incorporates probabilistic contextual information obtained from a language model into the single or multi-trial event related potential (ERP) decision mechanism. This tight fusion of contextual information with instantaneous and independent brain activity is demonstrated to potentially improve accuracy in a dramatic manner. Specifically, a simple regularized discriminant single-trial ERP classifier's performance can be increased from a naive baseline of 75% to 99% in a 28-symbol alphabet operating at 5% false ERP detection rate. We also demonstrate results which show that trained healthy subjects can achieve real-time typing accuracies over 90% mostly relying on single-trial ERP evidence when supplemented with a rudimentary n-gram language model. Further discussion and preliminary results include our initial efforts involving a locked-in individual and our efforts to train him to improve his skill in performing the task.

Track G. Architecture and Implementation

Session: MAb8 – Computer Arithmetic I **10:15 AM – 12:00 PM**

Chair: ***Roger Woods,*** *Queen's University Belfast,*

MA8b1-1

Efficient Decimal Leading Zero Anticipator Designs

Mohamed H. Amin, Ahmed M. ElTantawy, Alhassan F. Khedr, Hossam A. H. Fahmy, Cairo University

Abstract— The leading zero anticipator (LZA) is a vital block in fast floating point addition and fused multiply-add (FMA) operations. So far, there is only one decimal LZA proposed in research literature. This paper introduces two decimal LZA designs, then a comparison between the three designs, the two proposed here and the previous proposed one, is performed.

MA8b1-2
Hybrid Residue Generators for Increased Efficiency
Michael Sullivan, Earl Swartzlander, The University of Texas at Austin

In order for residue checking to effectively protect computer arithmetic, designers must be able to efficiently compute the residues of the input and output signals of functional units. Low-cost, single-cycle residue generators can be readily formed out of two's complement adders in two ways, which have area and delay tradeoffs. A residue generator using adder-incrementers for end-around-carry adders is small but slow, and a design using carry-select adders is fast, but large. It is shown that a hybrid combination of both approaches is more efficient than either.

MA8b1-3
Nested Quadratic Arithmetic for Efficient Convolution of Complex Sequences with Quadratic Modified Fermat Number Transforms
Chandrashekar Radhakrishnan, University of Illinois; Kenneth Jenkins, Pennsylvania State university

Recently the Modified Fermat Number Transform (MFNT) based on Right Circular Convolution (RCC) was extended to form a Quadratic MFNT (QMFNT) by introducing Left Circular Convolution (LCC) and interpreting the combined result as a quadratic representation of the resulting convolution output. The QMFNT enables efficient convolution/correlation to be implemented by overlap-add block processing without zero padding. This paper investigates the nesting of two distinct quadratic number representations, one associated with QMFNT block processing and the second with the quadratic coding for complex data sequences. The quadratic coding of complex data sequences combined with QMFNT block processing results in a computationally efficient strategy for convolving complex data sequences.

MA8b1-4
On Building General Modular Adders from Standard Binary Arithmetic Components
Ghassem Jaberipur, Shahid Beheshti University; Behrooz Parhami, University of California, Santa Barbara; Saeed Nejati, Shahid Beheshti University

We introduce an excess-delta residue representation for residue number system (RNS) arithmetic, in which a flag bit selects one or the other subrange within the full range of n-bit values. We show that our new representation leads to simple modular arithmetic with arbitrary residues, while using standard arithmetic components such as carry-save and carry-propagate adders that have been extensively optimized for area, power, and a host of other composite figures of merit. Further advantages of a unified treatment, as opposed to a multiplicity of specialized schemes previously proposed in connection with particular classes of moduli such as 2^n +- 1 and 2^n - 2^k +- 1, include simplified design process, verification, testing, and fault tolerance. Both gate-level analyses and VLSI synthesis results point to advantages in latency, area, and/or power compared with other proposed designs in the literature.

MA8b1-5
A Novel Adaptive Filter Implementation Scheme Using Distributed Arithmetic
Rui Guo, Linda S. DeBrunner, Florida State University

In this work, a distributed arithmetic (DA) based FIR adaptive implementation scheme is proposed. Different from existing DA schemes, our proposed scheme stores the sums of delayed and scaled input samples in look-up tables (LUTs) with binary coefficients as addresses. With least mean square (LMS) adaptation, offset-binary coding (OBC) based LUT updating method is presented as well. Simulation results show that a high speed, low computation and memory cost LMS adaptive filter can be realized by implementing our proposed scheme.

MA8b1-6
A Mixed-Precision Fused Multiply and Add
Nicolas Brunie, Kalray; Florent de Dinechin, École Normale Supérieure de Lyon; Benoit de Dinechin, Kalray

The floating-point fused multiply and add, computing R=AB+C with a single rounding, is now an IEEE-754 standard operator. This article investigates variants in which the addend C and the result R are of a larger format, for instance binary64 (double precision), while the multiplier inputs A and B are of a smaller format, for instance binary32 (single precision). Like the standard FMA operator, the proposed mixed-precision operator computes AB+C with a single rounding, and fully support subnormals. With minor modifications, it is also able to perform the standard FMA in the smaller format, and the standard addition in the larger format. For sum-of-product applications, the proposed mixed-precision FMA provides the accumulation accuracy of the larger format at a cost that is shown to be only one third more than that of a classical FMA in the smaller format. Besides, we show that such a mixed-precision FMA, although not mentioned in existing standard (IEEE 754, C and Fortran), is perfectly compliant to these standards. For DSP and embedded applications, a mixed binary32/binary64 FMA will enable binary64

computing where it is most needed, at a small cost overhead with respect to current binary32 FMAs, and with fewer data transfers, hence lower power than a pure binary64 approach. In high-end processors, a mixed binary64/binary128 FMA could provide an adequate solution to the binary128 requirements of very large scale computing applications.

MA8b1-7
Implementation of 32-bit Ling and Jackson Adders
Matthew Keeter, David Harris, Andrew Macrae, Rebecca Glick, Madeleine Ong, Harvey Mudd College; Justin Schauer, Oracle

Ling adders factor complexity out of the first stage of an adder to shorten the critical path. In 2004, Jackson and Talwar proposed a generalization of the Ling adder that reduces the complexity of the critical generate path at the expense of increased complexity in the propagate logic. This paper compares implementations of 32-bit Ling and Jackson adders to the optimized Sklansky architecture produced by Design Compiler in a 45 nm process. The Ling adder is 3% faster and uses 7% less energy, achieving a delay of 8.3 FO4 inverters. The Jackson adder is only 1% faster and uses 45% more energy. However, this is the first published implementation of a Jackson adder with all details shown.

MA8b1-8
Truncated-Matrix Multipliers with Coefficient Shifting
E. George Walters III, Penn State Erie, The Behrend College; Michael J. Schulte, Advanced Micro Devices

Truncated-matrix multipliers offer significant reductions in area, power, and delay, at the expense of increased computational error. These tradeoffs make them an attractive choice for many signal processing systems such as FIR filters. This paper presents a method for shifting coefficients that significantly reduces the error introduced by eliminating partial product columns. This method allows further reductions in area, power, and delay while maintaining the overall error performance of the system.

Track A. Communications Systems
Session: MAb8 – Physical Layer Security I 10:15 AM – 12:00 PM
Chair: ***Wing-Kin (Ken) Ma,*** *Chinese University of Hong Kong*

MA8b2-1
Faster than Nyquist Interference Assisted Secret Communication for OFDM Systems
Arsenia Chorti, H. Vincent Poor, Princeton University

In this work, secure broadcasting of orthogonal frequency division multiplexing (OFDM) signals is explored. The work begins with a synopsis of key published results for the secrecy capacity of OFDM systems, as well as practical proposals for the secure transmission of OFDM signals at the physical layer. Subsequently, the merits and demerits of employing faster than Nyquist (FTN) signalling techniques are investigated in the context of interference assisted secret communication for OFDM systems. The superposition property of the wireless medium is exploited to compromise the ability of an eavesdropper to extract the OFDM from the FTN signal.

MA8b2-2
QoS-Constrained Robust Beamforming in MISO Wiretap Channels with a Helper
Jing Huang, A. Lee Swindlehurst, University of California, Irvine

In this paper, we develop robust beamforming strategies for multiple-input single-output (MISO) wiretap channels with a helper. The channel state information (CSI) for the legitimate link is assumed to be available while the CSI for the eavesdropper's channel is imperfect, and is assumed to be norm-bounded by some known constant. We optimize the worst-case performance for the following problems: 1) minimizing the signal to interference-plus-noise ratio (SINR) at the eavesdropper while maintaining an SINR constraint at the intended receiver, 2) maximizing the SINR at the intended receiver while forcing an SINR constraint at the eavesdropper, and 3) minimizing the global transmit power while satisfying SINR constraints at both the legitimate user and the eavesdropper. Simulation examples show the advantages of the robust designs over the non-robust counterparts.

MA8b2-3
Secrecy Outage in MISO Systems with Partial Channel Information
Sabrina Gerbracht, Eduard Jorswieck, Dresden University of Technology

We consider the achievable outage secrecy rate of a wireless link with multiple antennas at the transmitter and single antennas at receiver and eavesdropper. Only the channel mean to the eavesdropper is known. The optimal beamforming vectors are characterized and certain closed form expression for the achievable outage secrecy rate are derived. Another transmit strategy

with artificial noise is proposed and the optimal beamforming and power allocation is analyzed. The impact of system parameters as required rate, number of antennas, SNR working point, and channel knowledge are discussed analytically and by numerical simulations.

MA8b2-4
Secrecy Rate for Gaussian MISO Wiretap Channels with Spherical Uncertainty

Jiangyuan Li, Athina Petropulu, Rutgers University

A Gaussian multiple-input single-output (MISO) wiretap channel model is considered, where there exists a transmitter equipped with multiple antennas, a legitimate receiver and an eavesdropper each equipped with a single antenna. We study the problem of finding the optimal input covariance that achieves worst-case secrecy rate subject to a power constraint, under spherical uncertainty for both legitimate and eavesdropper channels. We first show that the problem has a rank one solution, i.e., beamforming is optimal. With this, the problem is reduced and a closed form solution is obtained (which is equivalent to find one of eigenvalues of a known 6-by-6 matrix). Numerical results are presented to illustrate the method.

MA8b2-5
Two-Way Discriminatory Channel Estimation for Non-Reciprocal Wireless MIMO Channels

Chao-Wei Huang, Tsung-Hui Chang, National Tsing Hua University; Xiangyun Zhou, University of Oslo; Y.-W. Peter Hong, National Tsing Hua University

Discriminatory channel estimation (DCE) that utilizes two-way training is examined for non-reciprocal wireless MIMO channels. Here, a system that consists of a transmitter, a legitimate receiver (LR), and an unauthorized receiver (UR) is considered. The goal of DCE is to discriminate the channel estimation performances at LR and UR by embedding artificial noise (AN) in the training signal sent by the transmitter. To minimize the effect of AN on LR, the transmitter must acquire sufficient knowledge of the downlink channel, which is difficult to do in non-reciprocal channel environments. In this work, a three phase training strategy is proposed to achieve this task. The training signals are designed to minimize the channel estimation error at LR subject to a constraint on that at UR. Simulation results are presented to demonstrate the effectiveness of the proposed method.

MA8b2-6
Safe Convex Approximation to Outage-Based MISO Secrecy Rate Optimization under Imperfect CSI and with Artificial Noise

Qiang Li, Wing-Kin Ma, Anthony Man-Cho So, Chinese University of Hong Kong

Consider the scenario of an MISO channel overheard by multiple single-antenna eavesdroppers. The transmitter has perfect channel state information (CSI) with the legitimate channel, but has imperfect CSI with the eavesdroppers' channels. The CSI uncertainties are assumed stochastic. We formulate an artificial-noise (AN)-aided secrecy-rate maximization problem where the CSI uncertainties are handled using an outage-based formulation. Our aim is to find, for this problem, tractable designs for the transmit and AN covariances. Unfortunately, outage-based optimization problems are generally difficult to solve. The main contribution here is to derive a safe, convex optimization-based, approximation to the considered problem. The advantages of the proposed method are shown by simulations.

MA8b2-7
Benefits of Multiple Transmit Antennas in Secure Communication: A Secrecy Outage Viewpoint

Xi Zhang, Hong Kong University of Science and Technology; Xiangyun Zhou, University of Oslo; Matthew McKay, Hong Kong University of Science and Technology

This paper investigates the benefits of multi-antenna transmission in secure communication without the eavesdropper's channel state information. We use a recently developed secrecy outage formulation, which separately measures the reliability of communication and the level of security against eavesdropping. The use of multiple transmit antennas enables the transmitter to strengthen the signal reception at the intended receiver while simultaneously confusing the eavesdropper by generating artificial noise. We characterize the security performance using the secrecy outage probability and show that an arbitrarily low secrecy outage probability cannot be achieved by adding more transmit antennas alone without optimizing other system parameters. To facilitate the practical system design, we consider an on-off transmission scheme with optimal artificial noise power, which minimizes the secrecy outage probability whilst guaranteeing a minimum quality of service requirement.

MA8b2-8
Strong Secrecy in Bidirectional Relay Networks
Rafael F. Wyrembelski, Holger Boche, Technische Universität München

Research developments show that the concept of bidirectional relaying significantly improves the performance in wireless networks. It applies to three-node networks, where a relay node establishes a bidirectional communication between two other nodes using a decode-and-forward protocol. In this work, the relay additionally integrates the transmission of a confidential message to one node which has to be kept secret from the other, non-legitimate node. This necessitates the study of the bidirectional broadcast channel with confidential messages for which we establish the secrecy capacity region employing the concept of strong secrecy. The strong notion of secrecy does not tolerate the non-legitimate node to obtain any amount of the confidential information. This is in contrast to the concept of weak secrecy based on equivocation rate which is usually considered.

Track A. Communications Systems
Session: MAb8 – Physical Layer Security II 10:15 AM – 12:00 PM
Chair: ***Wing-Kin (Ken) Ma,*** *Chinese University of Hong Kong*

MA8b3-1
A Full-Duplex Active Eavesdropper in MIMO Wiretap Channels: Construction and Countermeasures
Amitav Mukherjee, A. Lee Swindlehurst, University of California, Irvine

We examine the design of a full-duplex active eavesdropper in the 3-user MIMOME wiretap channel, where all nodes are equipped with multiple antennas. The adversary intends to optimize its antenna array and jamming signal parameters so as to minimize the MIMO secrecy rate of the main channel. The full-duplex operating mode of the adversary induces self-interference at its receive terminal, which is factored into the adversary's optimization. We characterize the worst-case jamming covariance for arbitrary and Gaussian input signaling, and develop a numerical algorithm to compute the same. We then examine sub-optimal active eavesdropping schemes that comprise essentially an antenna selection problem for the adversary. Finally, for a Rayleigh fading scenario we propose a countermeasure by allowing the transmitter to allocate some of its spatial dimensions for jamming the eavesdropper, and pose their strategic interactions as a zero-sum game with the MIMO secrecy rate as the payoff function.

MA8b3-2
RF Fingerprinting of Users Who Actively Mask Their Identities with Artificial Distortion
Adam Polak, Dennis L. Goeckel, University of Massachusetts Amherst

Variations in the RF chain of radio transmitters caused by imperfections of manufacturing processes can be used as a signature to uniquely associate wireless devices with a given transmission. In this work, sophisticated criminals that, when masquerading, intentionally introduce nonlinear distortions to the data symbols in order to fake their RF signatures are considered for the first time. We introduce an identification method that can be successfully employed even when the sophisticated, masquerading users modify their data symbols. Using parameters obtained from the measurements of commercially used RF transmitters, we demonstrate the utility of our approach.

MA8b3-3
Power Allocation to Noise-Generating Nodes for Cooperative Secrecy in the Wireless Environment
Kyle Morrison, Dennis L. Goeckel, University Massachusetts Amherst

The wireless scenario opens up opportunities for Eve to intercept a secret message between Alice and Bob, particularly in the case where Eve is much closer to the source than Bob. To improve secrecy, we employ a protocol where other system nodes generate noise to disrupt Eve and consider the optimal power that should be employed by each noise-generating node.

MA8b3-4
Comparing Random Signals with Application to Wireless User Authentication
Jitendra Tugnait, Auburn University

We consider a physical layer approach to enhance wireless security by using the unique wireless channel state information (CSI) of a legitimate user to authenticate subsequent transmissions from this user, thereby denying access to any spoofer whose CSI would significantly differ from that of the legitimate user by virtue of a different spatial location. Past approaches have explicitly

utilized underlying CSI estimated from data: is the CSI of the current transmission (packet) the same as that of the previous transmission? In this paper we formulate this problem as one of comparing two random signal realizations to ascertain whether they have identical power spectral densities. A binary hypothesis testing approach is formulated and illustrated via simulations.

MA8b3-5
Transmit Beamforming and Cooperative Jamming for MIMOME Wiretap Channels

Wei Shi, James Ritcey, University of Washington

Joint transmit beamforming and cooperative jamming for MIMOME (multiple-input multiple-output multi-antenna-eavesdropper) wiretap channel is studied, where the model consists of a transmitter, a friendly jammer, a receiver and an eavesdropper. The optimization problem of finding transmit and jamming covariances to maximize the secrecy rate is non-convex, and blindly searching will result in local optimums. Because of the transmit beamforming, the MIMOME channel is effectively a MISOSE channel, assuming the receiver and eavesdropper use their each beamformers. Using the 1-dim result of MISOSE channels in our previous work, we propose an iterative algorithm that in each iteration searches on the 1-dim space of a effective MISOSE channel and then update the effective MISOSE channel. Numerical results show that our proposed algorithm achieves higher objective whereas blind search is trapped at local optimums. The proposed algorithm achieves higher secrecy rate than the existing artificial noise scheme.

MA8b3-6
Secrecy in Broadcast Channels with Receiver Side Information

Rafael F. Wyrembelski, Universitat Munchen; Aydin Sezgin, Ulm University; Holger Boche, Universitat Munchen

We study secret communication for broadcast channels with two legitimate receivers and one eavesdropper. The transmitter sends two independent confidential messages to both legitimate receivers which have to be kept secret from the eavesdropper. Here, each receiver is interested in its own message having the other confidential message already as side information available. We provide inner and outer bounds on the secrecy capacity region. This problem arises for example in the broadcast phase of a bidirectional relaying network, where a relay node establishes a bidirectional communication between two nodes while keeping the communication secure from eavesdroppers outside the network.

MA8b3-7
Coherent Demodulation of AIS-GMSK Signals in Co-Channel Interference

Douglas Nelson, Joseph Hopkins, U.S. Department of Defense; Anthony Bartos, Welkin Associates, Ltd.

Gaussian Minimum Shift Keying (GMSK) modulation is used by GSM phone networks, the maritime Automatic Identification System (AIS) and other communication systems. These systems are designed to handle large numbers of users by time and frequency management. However, when the system is heavily loaded, the signals may interfere with each other, resulting in co-channel interference. We demonstrate accurate and effective methods to blindly estimate and track GMSK signal parameters needed for signal demodulation, including carrier frequency, carrier phase, baud rate, baud center and modulation index. We further demonstrate the use of these parameters in the demodulation of the signal even in severe noise and co-channel interference.

MA8b3-8
Secure Wireless Multicasting Through Nakagami-m Fading MISO Channel

Md. Zahurul I. Sarkar, Tharmalingam Ratnarajah, Queen’s University Belfast

In the group-oriented applications such as military and commercial wireless cellular networks often require the same data to be conveyed to multiple users simultaneously. This technique is usually referred to as physical layer multicasting. In this paper, we consider the problem of secret communication over Nakagami-m fading multiple-input single-output (MISO) channel, where a single transmitter sends a common and confidential message to a group of receivers in the presence of an eavesdropper. We are interested in protecting this message from eavesdropping. At first, we define the secrecy multicast capacity for a K-receiver multicast channel at which the eavesdropper is unable to decode any information from the multicast channels and find the analytical expression for the lower bound of average secrecy multicast capacity. Then, we define the secrecy multicast capacity in terms of secure outage probability, and find the analytical expressions for the probability of non-zero secrecy multicast capacity and secure outage probability to study the outage behavior of the proposed model.

Session: MAb8 – Image, Video Coding and Analysis 10:15 AM – 12:00 PM

Chair: ***Vishal Monga,*** *Pennsylvania State University*

MA8b4-1

JPEG Image Compression Using Quantization Table Optimization Based on Perceptual Image Quality Assessment

Yuebing Jiang, Marios Pattichis, University of New Mexico

We consider the use of perceptual image quality assessment in JPEG compression parameter optimization. For evaluating performance, we consider the use of the Structural Similarity Index (SSIM) for evaluating distortion in the compressed images. This leads to the study of rate-SSIM curves that replace the traditional use of rate-distortion curves based on the PSNR. We introduce a multi-objective optimization framework for estimating the best rate-SSIM curves. A new neighborhood system is defined for generating a Markov Chain search space for use with Simulated Annealing optimization. We report results on the Lena image and the LIVE image quality assessment database.Compared to the use of the standard JPEG quantization table, our results indicate that the new optimization approach allows for significant bitrate reductions (from -10.51% to -29.70%) while preserving the SSIM quality index (changes from -0.56% to +0.33%). The new rate-SSIM plots appear significantly improved over the standard JPEG rate-SSIM curves.

MA8b4-2

Efficient Coders for Large Tree-Structured Dictionaries of Tilings

Kai-Lung Hua, National Taiwan University of Science and Technology; Rong Zhang, Qualcomm Incorporated; Mary Comer, Ilya Pollak, Purdue University

Algorithms for best basis search in tree-structured dictionaries have been effectively used for many problems. An important class of best basis algorithms are methods that search for an optimum rectangular tiling for a block. These methods have proven to be promising in image and video compression, due to their ability to adapt to the geometry of motion in video coding applications and to the geometry of image textures and shapes in still picture coding. A major impediment to their practical use is the need to encode the tiling chosen by the encoder. If this is not done carefully, the resulting overhead bits may completely negate the advantages offered by the adaptivity of the tiling. In this paper, we devise efficient entropy coders for two large dictionaries. We show that our algorithms result in very significant savings compared to naive fixed-length encoding methods, and illustrate them using a video coding application.

MA8b4-3

Variable Block Size-Based MCFI with Fixed Block Size Motion Estimation

Masaru Hoshi, Akihiro Yoshinari, Yuichi Tanaka, Madoka Hasegawa, Shigeo Kato, Utsunomiya University

Recently, motion-compensated frame interpolation (MCFI) has been paid attention for frame rate up-conversion. However, distortions will occur at block boundaries since motion vectors (MVs) are usually estimated in a block-by-block manner. In this paper, we propose a MCFI method using motion compensation with variable block size. To simplify time-consuming motion estimation, we derive motion vectors for macro blocks with various block sizes from the MVs obtained by motion estimation with a fixed block size. The experimental results show the effectiveness of our MCFI compared with the fixed block size based-method.

MA8b4-4

A Structural Similarity Assessment for Generating Hybrid Images

Keita Takahashi, Madoka Hasegawa, Yuichi Tanaka, Shigeo Kato, Utsunomiya University

We discuss a structural similarity assessment for generating hybrid images. A hybrid image consists of two images. One is edge information of a foreground image and the other is coarse features of a background image. Visibility of the hybrid image depends on the viewing distance and the structural similarity of the images. This property of the hybrid image is useful for the application of graphical password. However, an evaluation method for checking if the background is appropriate to overlay with the foreground has not been established. To address this issue, we utilize Speeded Up Robust Features (SURF) to evaluate structural similarity of two images.

MA8b4-5
A Compact Saliency Model for Video-Rate Implementation
Tien Ho-Phuoc, Laurent Alacoque, Antoine Dupret, CEA; Anne Guérin-Dugué, GIPSA-Lab; Arnaud Verdant, CEA

Salient regions are useful for priority processing of fixation areas in case of limited computational or bandwidth resources. This paper presents an efficient and compact saliency model, compatible with image sensors implementation. Contrary to Itti's model of reference, our model relies on a low-complexity processing consisting of inter-frame difference, spatial contrast, and a central bias. Simple weighted combinations of these saliency components show better results than Itti's model. Moreover, a combination using time-varying weights further improves the performance; and results show that spatial saliency should be integrated after motion saliency. Besides, an original criterion is proposed to evaluate the models.

MA8b4-6
Dithered Soft Decision Quantization for Baseline JPEG Encoding and its Joint Optimization with Huffman Coding and Quantization Table Selection
En-hui Yang, Chang Sun, University of Waterloo

Based on baseline JPEG, a new image coding framework is first developed, where dithered quantizers are used to replace JPEG uniform quantizers for the purpose of improving the rate-distortion (R-D) performance without sacrificing the coding complexity instead of the conventional subjective image quality. By combining dithering with soft decision quantization (SDQ) — yielding dithered SDQ, an iterative algorithm is then proposed for jointly designing dither table, quantization table, run-length coding, and Huffman coding. When compared with state-of-the-art baseline JPEG R-D optimizer proposed recently by Yang and Wang, our algorithm achieves comparable and sometimes better R-D performance with about 65% computational complexity reduction.

MA8b4-7
Compressive Sensing Based Imaging via Beleif Propagation
Preethi Ramchandara, Mina Sartipi, University of Tennessee Chattanooga

In this paper, we present an imposing algorithm named multiple description coding using compressive sensing for image compression, which mainly aims at restoring the image from a small subset of samples with reasonable accuracy. The main advantage of this algorithm is that, the decoding complexity is greatly reduced and also the performance is superior compared to other current algorithms. In addition to the proposed algorithm, we came up with an alternative approach to retrieve the original image from the descriptions that are generated. The benefit of this approach is that it does not comprise of any transform method to obtain the sparse signal but uses the wavelet sparsity matrix to generate the sparse signal. Thus, it further condenses the decoding complexity and also inexpensive compared to other techniques.

MA8b4-8
An SVD Approach for Data Compression in Emitter Location Systems
Mohammad Pourhomayoun, Mark Fowler, Binghamton University

In classical TDOA/FDOA emitter location methods, pairs of sensors share the received data to compute the CAF and extract the ML estimates of TDOA/FDOA. The TDOA/FDOA estimates are then transmitted to a common site to estimate the emitter location. In some recent methods, it has been proposed to send the entire CAF rather than the TDOA/FDOA estimates to get better results. Thus, it is desirable to use some methods to compress the CAFs. In this paper, we will propose an SVD approach for CAF data compression. We will see that SVD approach is a beneficial method for data compression and also it is a strong tool for de-noising. Simulation results show that by applying SVD Data Compression it is possible to perform accurate location estimation in spite of the fact that we transmit fewer bits. Also for smaller compression ratio, we even achieve an improvement in performance of location estimation compared to the case that we do not compress the data at all and that is because of the de-noising effect of the SVD.

Session: MAb8 – Adaptive Systems and Spectral Estimation 10:15 AM – 12:00 PM

Chair: ***Vitor Nascimento,*** *University of Sao Paulo*

MA8b5-1

A Modified System-Based Adaptive Algorithm for a Sparse Reconfigurable Photonic Filter

Suk-seung Hwang, Hong Chang, Chosun University; John J. Shynk, University of California, Santa Barbara

Adaptive algorithms play a key role in a sparse reconfigurable adaptive filter (SRAF) for photonic switches. In this paper, we propose a modified system-based (MSB) algorithm whose performance can be evaluated mathematically for the SRAF. The MSB adaptive algorithm not only has good performance for white and non-white input signals, but also has better efficiency than conventional approaches such as previous cross-correlation-based (CCB) and system-based (SB) algorithms because of a reduced computational complexity. In order to improve the convergence rate of the algorithm, the MSB separately updates each row or column of the switch weight matrix. We also consider a specific structure for the intermediate desired signals, and present a computer simulation example to demonstrate the performance of the proposed adaptive SRAF algorithm for a system identification application.

MA8b5-2

A New Variable Step-Size Strategy For Adaptive Networks

Muhammad Bin Saeed, Azzedine Zerguine, King Fahd University of Petroleum & Minerals

Several algorithms have been developed over the last few years that utilize the distributed nature of an ad hoc wireless sensor network to estimate a certain parameter of interest. One such algorithm is called the diffusion least mean squares (DLMS) algorithm. This algorithm estimates the parameter of interest using the cooperation between neighboring sensors within the network. Among the various algorithms that improved the performance of the DLMS algorithm is the Variable Step-Size DLMS (VSSDLMS) algorithm. The VSSDLMS algorithm used the instantaneous error energy to update the step-size. The algorithm showed remarkable improvement. In this work, a new strategy for updating the step-size by utilizing the distributed nature of the network is presented. The proposed algorithm was compared to other similar algorithms and found to exhibit better performance.

MA8b5-3

A Comparison of Methods for Estimating Broadband Noise in the Frequency Domain

Don Hush, Norma Pawley, Kary Myers, Robert Nemzek, Los Alamos National Laboratory

Estimating the noise component of a signal that consists of sinusoids plus broadband noise is a ubiquitous problem. Most methods work in the time-domain, but frequency-domain methods can be computationally more efficient and invariant to the time-domain noise distribution. We compare two prominent frequency-domain approaches, one that computes statistics over periodograms of multiple time-segments, and the other that computes statistics over frequency-segments from a single periodogram. We explore the accuracy-resolution trade-off for both approaches and provide rigorous comparisons of accuracy (e.g. bias, variance), sample and segment size dependence, frequency resolution, and computational complexity.

MA8b5-4

An Information Filter for Voice Prompt Suppression

John McDonough, Carnegie Mellon University; Kenichi Kumatani, Disney Research; Bhiksha Raj, Carnegie Mellon University; Jill Lehman, Disney Research

In this work, we compare two techniques for voice prompt suppression (VPS). The first is a straightforward adaptation of a conventional Kalman filter, which has certain advantages over the normalized least squares algrithm in terms of robustness and speed of convergence. The second algorithm, which is novel in this work, is also based on a Kalman filter, but differs from the first in that the update or correction step is performed in information space and hence allows for the use of diagonal loading in order to control the growth of the subband filter coefficients, and thereby add robustness to the VPS.

MA8b5-5

Embedded Track Validation for Tree Search-Based Tracking of Maneuvering Targets

Hossein Roufarshbaf, Jill Nelson, George Mason University

We propose an integrated track validation scheme for tree search-based target tracking. Embedded within the search algorithm, the proposed approach improves the robustness of tree search-based tracking in the presence of uncertain target motion models and heavy clutter. A likelihood ratio test is employed for each track estimate considered (e.g. each path in the search

tree), and those falling below a threshold are eliminated. By pruning unlikely target paths from the search tree, the embedded track validation algorithm decreases the memory requirement of the tracker while concurrently improving tracking precision. Simulation results reveal improved tracker performance and demonstrate the effect of clutter and target maneuvers on the likelihood ratio.

MA8b5-6
Urban Terrain Multiple Target Tracking Using Probability Hypothesis Density Particle Filtering

Meng Zhou, Bhavana Chakraborty, Jun Jason Zhang, Arizona State University

The multiple target tracking problem in urban terrain environments is investigated in this paper by efficiently estimating target locations and velocities using probability hypothesis density (PHD) particle filters. The proposed approach aims to track multiple targets in urban environments with dense buildings. Numerical simulation results demonstrate that the proposed PHD particle filter can determine the number of targets without relevant a priori knowledge, can reason the birth and death of targets, and can achieve good tracking performance for a large number of targets with trackable computational complexity.

MA8b5-7
High-Resolution Non-Parametric Spectral Estimation Using the Hirschman Optimal Transform

Guifeng Liu, Victor DeBrunner, Florida State University

Abstract--- The traditional Heisenberg-Weyl measure quantifies the joint localization, uncertainty, or concentration of a signal in the phase plane based on a product of energies expressed as signal variances in time and in frequency. Unlike the Heisenberg-Weyl measure, the Hirschman notion of joint uncertainty is based on the entropy rather than the energy [1]. Furthermore, its definition extends naturally from the case of infinitely supported continuous-time signals to the cases of both finitely and infinitely supported discrete-time signals, and, as we noted in [2], the Hirschman optimal transform (HOT) is superior to the discrete Fourier transform (DFT) and discrete cosine transform (DCT) in terms of its ability to separate or resolve two limiting cases of localization in frequency, viz pure tones and additive white noise. In this paper we implement a stationary spectral estimation method using a matching pursuit method whose dictionary members are constructed from the combination of HOT-based and DFT atoms (elements)[3]. We call the resulting algorithm the HOT-DFT periodogram. We compare its performance (in terms of frequency resolution) with a standard DFT-based periodogram. In particular, we compare the performance of the HOT-DFT with that of the DFT in resolving two close frequency components in additive white Gaussian noise (AWGN). We find the HOT-DFT to be superior to the DFT in frequency estimation, and ascribe the difference to the HOT's relationship to entropy. We futhre confirm that the HOT based spectrum estimation shows superior frequency estimation to Quinn's DFT based methd [4] power spectrum estimation.

MA8b5-8
Co-Prime Sampling for System Stabilization with FIR Multi-Rate Controllers

P. P. Vaidyanathan, Piya Pal, California Institute of Technology

Coprime sampling has in the past found applications in fractional sampling rate alteration, spatial array processing, radar signal processing, system identification, and fractionally spaced channel-equalization. This paper revisits multirate feedback control systems in the context of coprime sampling theory. It is shown in particular that the system from the primary input to the output node can be stabilized with an FIR controller when the feedback rate is higher than the input and ouput rates. On the other hand, the system from the primary input to the feedback signal node can be stabilized with an FIR controller, whether the feedback rate is higher or lower than the input and output rates. These results hold under a coprimality assumption on certain transfer matrices which arise in the plant description. The assumption is mild in the sense that it is almost always satisfied in practice.

Track B. MIMO Communications and Signal Processing

Session: MPa1 – Interference-Alignment Techniques for Multi-Antenna Systems

Chair: ***Vincent Lau,*** *Hong Kong University of Science and Technology*

MP1a-1 **1:30 PM**

Interference Alignment for Peer-to-Peer Underlay MIMO Cognitive Radio Network

Huiqin Du, Tharmalingam Ratnarajah, Haichuan Zhou, Queen's University Belfast; Ying-Chang Liang, Institute for Infocomm Research

In this work, interference alignment is designed for peer-to-peer underlay MIMO cognitive radio network in which single primary user (PU) coexists with multiple secondary users (SUs). The proposed scheme chooses the transmit precoding and receiver interference subspace to minimize the total interference leakage while limiting the interference level to the PU. With perfect knowledge of local channel information, the optimization problem is solved iteratively, in which the transmitter and receivers take turns to update the precoding and interference receiving matrices, respectively. It is proven that the algorithm converges monotonically, and simulation results reveal the effectiveness of the proposed interference alignment scheme for cognitive radio network.

MP1a-2 **1:55 PM**

Sum Rate Enhancement by Maximizing SGINR in an Opportunistic Interference Alignment Scheme

Seong-Ho (Paul) Hur, University of California, San Diego; Bang-Chul Jung, Gyeongsang National University; Bhaskar D. Rao, University of California, San Diego

In this paper, we consider the opportunistic interference alignment scheme exploiting multiuser diversity in the interference-limited uplink cellular networks. The spatial degrees of freedom afforded by multiple receive antennas are partitioned into the signal dimension and interference dimension. We propose a method to enhance the sum rate by maximizing the signal to generated interference and noise ratio (SGINR) in each user. When multiple antennas are available in each user, we also propose a transmit beamforming scheme at each user in the direction to further maximize SGINR and investigate the optimal signal dimension at the base station. We show that the proposed methods greatly improve the sum rate compared to the conventional opportunistic scheme.

MP1a-3 **2:20 PM**

Interference Alignment for Partially Connected Quasi-static MIMO Interference Channel

Liangzhong Ruan, Vincent K.N. Lau, Hong Kong University of Science and Technology

Recent works on MIMO interference channels have shown that interference alignment can significantly increase the achievable degrees of freedom (DoF) of the network. However, most of these works have assumed a fully connected interference graph. In this paper, we investigate how the partial connectivity can be exploited to enhance system performance in MIMO interference networks. We propose a novel interference mitigation scheme which introduces constraints for the signal subspaces of the precoders and decorrelators to mitigate "many" interference nulling constraints at a cost of "little" freedoms in precoder and decorrelator design so as to extend the feasibility region of the interference alignment scheme. Our analysis shows that the proposed algorithm can significantly increase system DoF in symmetric partially connected MIMO interference networks. We also compare the performance of the proposed scheme with various baselines and show via simulations that the proposed algorithms could achieve significant gain in the system performance of randomly connected interference networks.

MP1a-4 **2:45 PM**

Opportunistic MU-MIMO based on Semi-Blind Interference Alignment

Haralabos Papadopoulos, Sayandev Mukherjee, Sean Ramprashad, DoCoMo USA Labs

Recently, Wang etal [1] proposed MU-MIMO schemes without CSIT requirements that are not plagued by the resource and system overheads of CSIT-based MU-MIMO. These schemes exploit blind interference alignment and require terminals that can switch between multiple receive antenna modes. We consider MU-MIMO transmission via a form of semi-blind interference alignment, enabled by opportunistic user-pairing from features of the users' multipath intensity profiles. The associated MU-MIMO schemes are suitably remapped versions of those in [1] over the OFDM plane. The proposed schemes can improve the DoFs, with single or multi-antenna terminals, and without requiring antenna-mode switching or transmitter access to fast-changing CSI.

Session: MPb1 – Interference Alignment for the MIMO Interference Channel

Chair: ***Geert Leus,*** *Technical University of Delft*

MP1b-1 3:30 PM

Linear Interference Alignment and its Maximum Achievable Degrees of Freedom

Meisam Razaviyayn, Gennady Lyubeznik, Zhi-Quan Luo, University of Minnesota

In this work we study the maximum degrees of freedom that can be achieved by a linear interference alignment scheme for a generic MIMO interference channel. We give tight upper and lower bounds for this problem and use them to bench mark the performance of existing algorithms for interference alignment and sum-rate maximization.

MP1b-2 3:55 PM

MIMO Interference Alignment in Random Access Networks

Behrang Nosrat-Makouei, Radha Krishna Ganti, Jeffrey G. Andrews, Robert W. Heath, Jr., The University of Texas at Austin

In this paper we analyze a constant multiple-input-multiple-out interference channel where nodes randomly distributed on a plane wish to utilize interference alignment to reduce the point-to-point outage. We model the spatial distribution of the nodes as a single-parameter marked Poisson point process with a fixed sized cluster at each mark. We link the accuracy of the channel state information to the distance between the nodes and show that there exist switching points between all the interference alignment clusters accessing the channel simultaneously, random access to the channel among the interference alignment clusters and random access to the channel by individual nodes.

MP1b-3 4:20 PM

The Noisy MIMO Interference Channel with Distributed CSI Acquisition and Filter Computation

Francesco Negro, Eurecom; Umer Salim, Irfan Ghauri, Intel Corporation; Dirk Slock, Eurecom

We study the frequency-flat noisy MIMO interference channel (IFC) with initial assumption of no channel state information (CSI) neither at the base stations (BS) nor at the user equipments (UE). In the noisy IFC, interference is treated as noise and hence linear transmit (Tx) and receive (Rx) filtering is considered. A transmission strategy is proposed through which the BS and the UE get the necessary CSI for CSI based transmit and receive processing by channel training and analog channel feedback, corresponding to transmission overhead. Both FDD and TDD scenarios are considered (the details for which are not too different in this distributed approach). In the limited overhead approach considered, discrepancies arise between the local estimates of the global CSI established at the various Tx/Rx units, on the basis of which the local Tx/Rx filters are computed. These filters are computed by optimizing a lower bound (and close approximation) of the weighted sum rate, accounting for partial CSI. The approach allows for simple approximate sum rate expressions that can easily be optimized for any set of system parameters to unveil the trade-off between the cost and the gains associated to CSI acquisition overhead.

MP1b-4 4:45 PM

Secure Space-Time Block Coding via Artificial Noise Alignment

S. Ali A. Fakoorian, A. Lee Swindlehurst, University of California, Irvine

In this work, we present a secure STBC scheme for MIMO Gaussian wiretap channels. It is assumed that the transmitter has the receiver's CSI, but not that of the eavesdropper. We first propose a full-rate STBC scheme that allows for decoupled scalar decoding at the intended receiver, while an exhaustive search is required for ML decoding at the eavesdropper. Next we make the code more secure by including artificial noise symbols which at asymptotically high SNR are aligned with each other and subtracted from the information symbols at the intended receiver, but not separable at the eavesdropper. The enhancement of the physical-layer security that results from these two schemes is demonstrated via several numerical examples.

Session: MPa2 – Energy-Harvesting Wireless Networks

Chair: ***Osvaldo Simeone,*** *NJIT*

MP2a-1 1:30 PM

AWGN Channel under Time-Varying Amplitude Constraints with Causal Information at the Transmitter

Omur Ozel, Sennur Ulukus, University of Maryland

We consider the classical AWGN channel where the channel input is constrained to stochastic amplitude constraints that are independent of the channel and the message. This is an abstraction of an energy harvesting transmitter where code symbol energy is constrained to an exogenous energy arrival and there is no battery for energy storage. At each channel use, amplitude constraint process is realized and observed by the transmitter causally. Then, the transmitter sends a code symbol that complies with that current amplitude constraint. We derive capacity achieving scheme in this case.

MP2a-2 1:55 PM

Optimal Power Control for Energy Harvesting Transmitters in an Interference Channel

Kaya Tutuncuoglu, Aylin Yener, Penn State University

Energy harvesting in a wireless network provides mobility, reliability and ease of maintenance as well as being an environmentally friendly alternative. Design of wireless networks consisting of energy harvesting nodes requires revisiting fundamental principles including transmission policies in presence of new energy constraints due to stochastic energy harvesting. In this work, we consider the interference channel, a basic building block of a wireless network, when the transmitting nodes are energy harvesting communication devices. We identify the optimum power policies that utilize the available and storable energy and manage the interference in the channel simultaneously to best serve both links. We focus on cases where a centralized decision can be made for both transmitters given their battery states and energy harvesting processes.

MP2a-3 2:20 PM

Queuing Theoretic and Information Theoretic Capacity of Energy Harvesting Sensor Nodes

Vinod Sharma, Indian Institute of Science; Ramachandran Rajesh, Centre for Airborne Systems

Abstract: We consider a sensor node which replenishes its energy via an energy harvester, e.g., solar cell. Now, there is unlimited energy but it is generated at a certain rate. Thus, unlike a usual battery operated sensor node where one is concerned about the total life time of the node, one has the constraint on the rate at which one can consume the energy. In this set up one can ask about the stability region of data queue at the node, the information theoretic capacity and the steady state mean delays for a given data traffic. We will answer some of these questions even when some of the energy is consumed in sensing and data processing at the sensor node.

MP2a-4 2:45 PM

Queue and Power Control for Rechargeable Sensor Networks under the SINR Interference Model

Zhoujia Mao, Can Emre Koksal, Ness B. Shroff, Ohio State University

Renewable energy sources can be attached to sensor nodes to substantially improve the performance of sensor networks. In networks with renewable energy sources, conservative energy expenditure may lead to missed recharging opportunities due to the batteries being full, while aggressive usage of energy may cause the network to be intermittently disconnected and reduction in coverage. Thus, new techniques and algorithms must be developed for sensor networks with replenishment to balance these seemingly contradictory goals. In this paper, we consider a sensor network with renewable energy sources under the SINR interference model, where the achievable rate of each link depends on its SINR. We develop a provably efficient solution to maximize the total sensing rate subject to quality of service constraints, which is also possible for distributed implementation under time scale separation. Our solution is a joint rate control, power allocation, and routing algorithm which is computationally simple and applicable to non-rechargeable sensor networks as well.

Track A. Communications Systems

Session: MPb2 – Coding and Decoding

Chair: ***Aydin Sezgin,*** *University of Ulm*

MP2b-1 3:30 PM

Complexity Analysis of Interior Point Methods for LP Decoding

Yifan Sun, Lara Dolecek, University of California, Los Angeles

Linear programming (LP) decoders can outperform currently used message-passing decoders in channel coding applications, but require prohibitively large complexity on even moderately sized codes. Previous works have proposed complexity-reducing algorithms that either relax the problem or modify the number of constraints; however, little work is done in optimizing solver implementation. We show that popular LP solvers like LIPSOL may not be efficient for LP decoding (LPD), and that an equivalent dual LP problem can be solved with equal accuracy but much more quickly. We propose an improved primal-dual method (iPD-MPC) whose overall runtime for both problem formulations outperform LIPSOL. Additionally, as an alternative for memory-limited systems, we propose an improved hybrid gradient descent and Newton's method (iGD-NM) that further decreases overall runtime. In this way, we make LPD more feasible for channel codes of practical lengths.

MP2b-2 3:55 PM

Rate Adaptive Non-Binary LDPC Codes with Low Encoding Complexity

Nicholas Chang, MIT Lincoln Laboratory

For error-correction codes, the optimal coding rate can vary and depend on factors including channel, time-varying fading, environmental interference, power or bandwidth allocation, communication content and application. Rate adaptive coding schemes are thus important for robust communications. This writeup proposes and studies a rate-adaptive low density parity check (LDPC) coding scheme using nonbinary Galois fields (GF). The algorithm uses a single low complexity encoding structure, but maintains strong near-capacity performance at arbitrary rational rates. The rate adaptive encoder can be used in a space-time code for multiple-input multiple-output (MIMO) communication systems and is shown to achieve near capacity performance at various rates and different MIMO configurations.

MP2b-3 4:20 PM

Achieving Flexibility in LDPC Code Design by Absorbing Set Elimination

Jiajun Zhang, Jiadong Wang, University of California, Los Angeles; Shayan Garani Srinivasa, Western Digital Corporation; Lara Dolecek, University of California, Los Angeles

Low-density parity-check (LDPC) codes are attrac- tive since their performance is known to approach the Shannon limits for suitably large block lengths. However, for moderate block lengths error floors still jeopardize the performance even of well-designed LDPC codes. Previous work has shown that the error floor of a broad class of LDPC codes is due to certain graphical structures called absorbing sets. Separable, circulant-based (SCB) codes represent a general family of high-performance, hardware-friendly LDPC codes built out of circulant matrices. Applying the row selection and column elimination (CE) methods on SCB codes can dramatically decrease error floors by avoiding certain small dominant absorbing sets in a principled way. This paper will focus on improving the CE method used on SCB codes in order to achieve greater flexibility in code rate while provably avoiding small dominant absorbing sets. Flexibility and low implementation complexity are therefore possible without sacrificing code performance.

MP2b-4 4:45 PM

Decoding by Detection: Soft-Input/Soft-Output Error Correction Decoders for Arbitrary Binary Linear Codes

Todd Moon, Jacob (Jake) Gunther, Utah State University

We present a method for decoding arbitrary binary linear codes using soft-input/soft-output decoding using an iterative decoder. The method works by modeling the channel posterior probability or log probability ratio of the received bits as noise term dependent upon (for example, translated according to) the coded bits. By representing the coded bits using their binary encoding operation, as a linear combination of the columns of the generator matrix G, a single column of G can be isolated to form a detection problem. The other columns of G represent a "noise" pattern which is modeled using Gallager's lemma, and which is incorporated into the overall likelihood function via conditioning. Results indicate that the method works for a linear codes over a variety of lengths, with performance at or exceeding the performance for hard-decision decoding.

Session: MPa3 – Graphical Models in Signal Processing II

Chair: ***Alex Ihler,*** *University of California, Irvine*

MP3a-1 1:30 PM

Regime Change: Bit-Depth versus Measurement-Rate in Compressive Sensing

Jason N. Laska, Richard Baraniuk, Rice University

The recently introduced compressive sensing (CS) framework enables digital signal acquisition systems to take advantage of signal structures beyond bandlimitedness. Indeed, the number of CS measurements required for stable reconstruction is closer to the order of the signal complexity than the Nyquist rate. To date, the CS theory has focused on real-valued measurements, but in practice, measurements are mapped to bits from a finite alphabet. Moreover, in many potential applications the total number of measurement bits is constrained, which suggests a tradeoff between the number of measurements and the number of bits per measurement. We study this situation in this paper and show that there exist two distinct regimes of operation that correspond to high/low signal-to-noise ratio (SNR). In the measurement compression (MC) regime, a high SNR favors acquiring fewer measurements with more bits per measurement; in the quantization compression (QC) regime, a low SNR favors acquiring more measurements with fewer bits per measurement. A surprise from our analysis and experiments is that in many practical applications it is better to operate in the QC regime, even acquiring as few as 1 bit per measurement.

MP3a-2 1:55 PM

Inference and Learning for Continuous-Time Stochastic Systems

Christian Shelton, E. Busra Celikkaya, University of California, Riverside

A continuous time Bayesian network (CTBN) is a compact description of a discrete-state continuous-time (or asynchronous) Markovian stochastic process. We discuss the semantics of the model, its comparison to other continuous time Markov process models, and how to estimate CTBN parameters and structure from complete or incomplete data. We review the existing methods for approximate inference in such a model and their relative advantages. Finally, we conclude with an example application of CTBNs to reason about information spread across social networks.

MP3a-3 2:20 PM

Approximate Bayesian Inference for Robust Speech Processing

Ciira Maina, John Walsh, Drexel University

Robust speech processing remains an active area of research due to the need to compensate for noise in real world speech applications. In this paper we present a review of Bayesian approaches to robust speech processing. In particular we focus on approximate Bayesian inference algorithms for speaker recognition and speech enhancement. We present variational Bayesian algorithms developed both in the time domain and in the log spectral domains and discuss issues relating system performance and complexity in both domains. This work leads naturally to the perfomance versus complexity tradeoff that dictates which approximate Bayesian algorithm to use in a given speech application and what performance we can expect.

MP3a-4 2:45 PM

Out-of-Sequence Measurements and Incremental Inference in Graphical Models

Ozgur Sumer, University of Chicago; Ramgopal Mettu, University Massachusetts Amherst; Umut Acar, MPI-SWS; Alexander Ihler, University of California, Irvine

Out-of-sequence measurements (OOSM) occur commonly in many networked estimation and signal processing applications. Delays due to routing or latency effects cause observations to arrive late, and state estimates for the current time must be "corrected" to account for older information. We describe the OOSM task within the framework of incremental (or adaptive) inference, which enable a model to be updated efficiently after small changes. This viewpoint leads to a set of efficient exact updates for filtering or smoothing in discrete or linear, Gaussian systems, and new approximate algorithms for more general problem settings.

Session: MPb3 – Signal Processing and Learning in Complex Systems

Chair: ***Andrew Singer,*** *University of Illinois at Urbana-Champaign*

MP3b-1 **3:30 PM**

Diffusion Adaptation over Networks of Particles Subject to Brownian Fluctuations

Ali H. Sayed, Faten Sayed, University of California, Los Angeles

This article investigates the influence of diffusion adaptation on the behavior of networks of micro-organisms that are subject to Brownian fluctuations in the motion of their constituent nodes. The organisms are assumed to share information through chemical signaling. The information may signal the direction of a target (such as a foreign body) towards which the cells need to migrate. The sharing of information allows the nodes to bias the probabilities of their random walks in favor of the desired direction. It is verified that the adaptive diffusion of direction information enhances the foraging and tracking ability of the cells and the mean-square performance of the location estimation process.

MP3b-2 **3:55 PM**

Trust, Opinion Diffusion and Radicalization in Social Networks

Lin Li, Anna Scaglione, University of California, Davis; Ananthram Swami, Army Research Laboratory; Qing Zhao, University of California, Davis

Gossiping models have increasingly been applied to study social network phenomena. In this context, this paper is specifically concerned with modeling how opinions of social agents can be radicalized if the agents interact more strongly with neighbors that share their beliefs. In our model, each agent's belief is represented with a continuous rating between zero and one. The agents average their opinions with that of their neighbors over time, weighting more opinions that are closer to their current beliefs. The increasing trust that may exist among likeminded agents is modeled through a weight that is a monotonically decreasing function of the distance in opinion. We consider a continuous (soft) and a discontinuous (hard) model for the weight and analyze the convergence properties. This model allows us to define an equivalent ``opinion graph'' whose evolution is tightly coupled with the radicalization of a society. We also explore what is the relative weight of the communication graph and of the opinion graph in the trend towards radicalization, and compare our results to the previous literature.

MP3b-3 **4:20 PM**

Disentangling Mixed Preference Systems and Hidden Variables

Constantine Caramanis, The University of Texas at Austin

We consider the problem of disentangling mixed preference systems and hidden variables, and applications to transmitting video over wireless networks.

MP3b-4 **4:45 PM**

Unity Versus Diversity in a Population of Interacting Adaptive Agents: the Value of Extrinsic Gossip

Andrew Bean, Andrew Singer, University of Illinois, Urbana-Champaign

In populations of interacting agents, it is sometimes possible for sub groups to arise, rather than the population converging to a unified whole. This can occur, in particular, when local interactions are reinforced in a manner reminiscent of short cycle behavior of iterative decoding of LDPC codes under belief propagation. In this paper, we study such fracturing of a population of diffusion-LMS adaptive agents, as well as how to encourage convergence toward a unified population through a measured restriction of local interaction to eliminate self-loops and pass only "extrinsic updates" between agents.

Session: MPa4 – Compressive Sensing Applications in Networking

Chair: ***Jarvis Haupt,*** *University of Minnesota*

MP4a-1 1:30 PM

Sparse Recovery of Temporally Changing Networks: Longitudinal Modeling of Brain Networks in Children

Moo Chung, Jamie Hanson, Seth Pollak, University of Wisconsin

We present a novel sparse data recovery framework for temporally changing networks. Correlation between nodes is confounded by the effect of other nodes. To factor out the dependency of other nodes, partial correlation is used. To reduce the dimensionality associated with the large number of nodes that far exceeds the number of measurements, the partial correlations are obtained from a sparse linear regression with LASSO. The sparse regression framework is then adapted to handle temporally changing networks by introducing time dependency in the model. The proposed framework is applied to characterizing longitudinal change in brain networks of 82 children.

MP4a-2 1:55 PM

Unveiling Anomalies in Large-Scale Networks via Sparsity and Low Rank

Morteza Mardani, Gonzalo Mateos, Georgios B. Giannakis, University of Minnesota

In the backbone of large-scale Internet Protocol (IP) networks, traffic flows experience abrupt (un)intentional changes, which result in congestion, and limit the extent to which end-user quality of service requirements can be met. Diagnosing such traffic volume anomalies is a crucial task towards engineering the traffic in the network. This is a challenging task however, since the available data are usually high-dimensional, noisy link-load measurements, comprising the superposition of unobservable network flows. Temporal correlations present among network flows render the traffic matrix low rank in the absence of anomalies, and principal component analysis-based methods have been proposed to capitalize on this property. However, such approaches need prior information on the rank of the traffic matrix, and face scalability issues. Most importantly, they have not exploited the sparsity of traffic anomalies across flows and time. In this context, the fresh look advocated here permeates benefits from nuclear norm minimization and compressive sampling, to unveil traffic volume anomalies in large-scale networks. Joint estimation of the anomalous flows and `clean' link-level traffic volumes is formulated as a convex optimization problem, which is efficiently solved and thus incurs complexity that scales gracefully with the network size. Distributed and real-time algorithms based on in-network processing of link-load measurements are also developed. Simulated tests and experiments with real network data corroborate the effectiveness of the novel scheme.

MP4a-3 2:20 PM

Random Access Compressed Sensing: An Integrated Architecture for Energy-Efficient Networking

Fatemeh Fazel, Northeastern University; Maryam Fazel, University of Washington; Milica Stojanovic, Northeastern University

We propose an integrated sensing and communication architecture whose goal is to achieve overall efficiency as measured in terms of the energy per bit of information successfully delivered to a fusion center. The proposed approach capitalizes on combining compressed sensing with random channel access. While the former supports transmission of sensor data from a random subset of the nodes, thus reducing the overall energy consumption, the latter supports a robust and simple implementation that eliminates the need for synchronization, scheduling, and downlink feedback. Because of the random nature of the system architecture, a probabilistic approach to system design is necessary. In this respect, we introduce the notion of sufficient sensing probability— the probability with which full field reconstruction is guaranteed in a certain interval of time. Setting this probability to a desired target value, system optimization under a relevant criterion such as the minimum energy per bit or minimum reconstruction time yields the necessary sensing rate. We specify a complete model for the network incorporating packet collisions, communication noise and channel fading.

MP4a-4 2:45 PM

Recent Results on Sparse Recovery over Graphs

Weiyu Xu, Meng Wang, Enrique Mallada, Ao Kevin Tang, Cornell University

In this paper, we will introduce and review our recent results in sparse recovery over graphs, which has made a new connection between coding theory and graph theory. We will also discuss the relevant applications of sparse recovery over graphs. ‘’

Session: MPb4 – Resource Allocation in Wireless Networks

Chair: ***Rahul Urgaonkar,*** *University of Southern California*

MP4b-1 **3:30 PM**

MSE-Optimal Power Allocation in Wireless Sensor Networks for Field Reconstruction Based on Shift-Invariant Spaces

Günter Reise, Vienna University of Technology; Javier Matamoros, Carles Antón-Haro, Centre Tecnològic de Telecomunicacions de Catalunya (CTTC); Gerald Matz, Vienna University of Technology

In our previous work, we developed field reconstruction methods in wireless sensor networks based on shift-invariant spaces. In this paper, we use amplify-and-forward for the transmission of the sensor measurements to the fusion center and we derive the mean square error (MSE) of the reconstructed field as a function of the measurement noise, the channel gains between sensors and fusion center, the receiver noise variance, and the sensor placement. Imposing a sum-power constraint, we formulate the MSE-optimal power allocation as a convex optimization problem that can be solved numerically. For the case of critical sampling we derive a closed-form expression for the optimal power allocation. For Gaussian channels and Rayleigh-fading channels, we compare the performance of the proposed power allocation schemes and uniform power allocation. The power allocation schemes provide new insights for our field reconstruction scheme and feature excellent performance while being easy to implement.

MP4b-2 **3:55 PM**

Spatial Interference Mitigation for Multiple-Input Multiple-Output Ad Hoc Networks

Salam Akoum, The University of Texas at Austin; Marios Kountouris, Mérouane Debbah, Supélec; Robert W. Heath, Jr., The University of Texas at Austin

We consider the role of multiple antennas in interference mitigation for multiple input multiple output (MIMO) ad hoc networks. We propose a new distributed spatial interference mitigation strategy based on zero forcing (ZF) nulling at the transmitter and ZF cancellation at the receiver. Assuming a network with Poisson distributed transmitters and independent Rayleigh fading channels, the achievable goodput in the ad hoc network is derived. Tools from stochastic geometry are applied to obtain the probability of outage, and the network throughput scaling. The results are compared to the state of the art in spatial interference cancellation for ad hoc networks, and shown to yield better network throughput performance.

MP4b-3 **4:20 PM**

A Greedy Link Scheduler for Wireless Networks with Fading Channels

A. Sridharan, Emre Koksal, Ohio State University

In this paper, we consider the problem of link scheduling for wireless networks with fading channels, where the link rates are varying with time. Due to the high computational complexity of the throughput optimal scheduler, we provide a low complexity greedy link scheduler with provable performance guarantees for wireless networks with fading channels. We show that the performance of our greedy scheduler can be analyzed using the Local Pooling Factor (LPF) of a network graph, which has previously been used to characterize the stability of the Greedy Maximal Scheduling policy

MP4b-4 **4:45 PM**

Radio Resource Management in Heterogeneous Deployments: a System Level Perspective

Thomas Wirth, Fraunhofer Heinrich Hertz Institute

New multimedia services such as HTTP live video streaming [1] demand for higher capacity, especially in mobile networks. In fact, about 50 % of data in mobile networks is currently video traffic, and this number is expected to increase to 70-80 % by 2015 [2]. To enhance the capacity in cellular networks even further, several study items were defined [3] to target peak data rates of up to 1 Gbit/s in the downlink and 500 Mbit/s in the uplink. The different techniques are currently being discussed within the 3GPP for LTEs evolution called LTE-Advanced (LTE-A). A promising approach to enhance the capacity in cellular access networks even further is to create smaller cells [4]. This represents a shift in paradigm from Macro cells to a more heterogeneous ecosystem consisting of a combination of different cell sizes and transmission powers and thus coverage, referred to as Macro-, Pico-, and Femto-cells. The key idea behind heterogeneous networks (HetNet) is that the frequency reuse factor (FRS) is set to 1, which means that all heterogeneous cells operate in the same frequency range, but can be controlled and optimized in frequency domain together. With FRS 1, cell capacity is strongly interference limited and interference management (IM) techniques are required at both base station (eNB) and user equipment (UE) to reach the target performance. Newly defined protocols between HetNet entities allow decentralized, feedback-based radio resource management (RRM) which can help to mitigate interference and enhance HetNet performance on a cellular level. The performance is measured by key performance indicators

(KPIs) [5] with performance criteria tailored to HetNet deployments. Aim of this paper is to evaluate RRM techniques which focus on a distributed precoding concept on system-level taking into account realistic antenna models optained by 3D antenna measurements.

Track F. Biomedical Signal and Image Processing

Session: MPa5 – Advances in Bioimaging and Analysis

Chair: ***Jean-Christophe Olivo-Marin,*** *Institut Pasteur*

MP5a-1 1:30 PM

Quantitative Synaptic Vesicle Imaging for Evaluating Neuron Activities in Neurodegenerative Diseases

Jing Fan, Xiaofeng Xia, Stephen Wong, Methodist Hospital Research Institute

Synaptic vesicle dynamics play an important role in studying neuronal and synaptic activities of neurodegenerative diseases ranging from epidemic Alzheimer's disease to rare Rett syndrome. To obtain significant statistical power in such studies, we developed a high content analysis (HCA) pipeline to visualize the vesicle dynamics and characterize the neuronal synaptic activities in a large population of neurons. Our experiments on hippocampal neuron assays showed that the proposed HCA system can automatically detect vesicles and quantify their dynamics for evaluating neuron activities. The availability of such an automated system would open up a vista to investigate synaptic neuropathology and identify candidate therapeutics of neurodegeneration.

MP5a-2 1:55 PM

Flexible and Efficient Multi-Region Segmentation Using Active Contours

Grégory Paul, Janick Cardinale, Ivo F. Sbalzarini, ETH Zurich

Multi-region image segmentation aims at partitioning an image into several "meaningful" regions. Apart from being computationally hard to solve, already formulating the problem in terms of an image model is difficult, since the number of regions and their relations within the image are to be accounted for. This particular aspect of segmentation becomes even more important in bio-imaging where the prior knowledge available can be weak. We propose both a modeling and a computational framework allowing multi-region active-contour segmentation where the number of regions is accommodated for in a flexible way. Examples from live-cell fluorescence microscopy are used to demonstrate the capabilities and limitations of the proposed approach.

MP5a-3 2:20 PM

Nanometer Resolution Imaging and Tracking of Axonal Cargo Transport in Normal and Degenerative Neurons

Ge Yang, Carnegie Mellon University

Survival and function of neuronal cells depend on bidirectional active transport of cargoes along axonal microtubules. Transport defects have been strongly implicated in many neurodegenerative diseases such as Alzheimer's disease. To understand related regulation and disease mechanisms, we developed a method to image and automatically track individual cargoes at a nanometer resolution and applied it to analyze cargo transport in live Drosophila larval neurons. Base on computational analysis of fine behavior of individual cargoes, we found that their movement in vivo follows multiple stereotypical patterns. Using these techniques, we characterized and compared cargo transport behavior of normal neurons and degenerative neurons of an Alzheimer's disease model.

MP5a-4 2:45 PM

Statistical Colocalization of Molecular Species in Biological Imaging

Vannary Meas-Yedid, Cyril Basquin, Nathalie Sauvonnet, Jean-Christophe Olivo-Marin, Institut Pasteur

Colocalization is a way to analyze relative proximities of two biological entities in cellular biology. However, very few methods address the question of statistical validation. We propose a method based on multiple hypothesis tests on the distance between all couples of the object mass center. Two objects are defined to be colocalized if the test on their distance is significant. Therefore, after object detection, we build a null hypothesis model in which the distribution of the distance between two independently randomly drawn detections in the cell is estimated by a kernel method. The observed distances are tested against this null model. This method has been successfully applied in a real problem of protein colocalization analysis during the endocytic process.

Session: MPb5 – Image/Video Restoration, Enhancement and Evaluation

Chair: ***Mary Comer,*** *Purdue University*

MP5b-1 3:30 PM

Tikhonov's Regularization Functional for Image Restoration by Means of q-Discrepancy

Vania V. Estrela, Universidade Federal Fluminense; Aggelos K. Katsaggelos, Northwestern University

This work employs Bregman distances as an alternative to solve the regularized image restoration problem. Bregman regularization gives accurate answers after just some iterations with fast convergence, better accuracy and stability. This technique has an adaptive nature: the regularization functional is updated according to Bregman functions that change from iteration to iteration according to the nature of the neighborhood under study at iteration n. Numerical experiments show that high-quality regularization parameter estimates can be obtained. The convergence is sped up while turning the regularization parameter estimation less empiric, and more automatic.

MP5b-2 3:55 PM

Equivalence of Plenoptic Cameras

Todor Georgiev, Adobe; Sergio Goma, Qualcomm Incorporated; Andrew Lumsdaine, Adobe

The Plenoptic camera captures full multi-view 3D information about the scene and thus makes much richer imaging applications possible. There are two types of plenoptic cameras: Those with lens array in front of the main camera lens, and those with microlens array behind the main camera lens. We show that the two types of plenoptic camera are optically equivalent. Also, we compute the parameters that establish that equivalence and show where each type of plenoptic camera is more useful than the other. We show exact parameters and working prototypes.

MP5b-3 4:20 PM

Referenceless Image Spatial Quality Evaluator

Anish Mittal, Anush Moorthy, Alan Bovik, Wireless Networking and Communications Group

We propose a natural scene statistic based Referenceless Image Spatial QUality Evaluator (RISQUE) which extracts marginal statistics of local normalized luminance signals and measures image naturalness (or lack there of) based on measured deviations from a natural image model. We also model the distribution of pairwise products of adjacent normalized luminance signals which provides distortion orientation information. Although multi scale, the model is defined in the space domain only avoiding costly frequency or wavelet transformations. The frame work is shown to perform statistically better than other proposed no reference algorithms and the full reference structural similarity index (SSIM) .

MP5b-4 4:45 PM

Noise Model Discrimination for Digital Images based on Variance-Stabilizing Transforms and on Local Statistics: Preliminary Results

Paul Rodriguez, Pontificia Universidad Catolica del Peru

Most of the image restoration algorithms assumed the noise model and its parameters as an a priori information. Nevertheless this is not necessarily the case for real scenarios. Moreover, lack of knowledge about the noise parameters leads to heuristically approaches to choose the restoration algorithm's parameters. Given a non-texture observed image, which can be noise-free or corrupted with some kind of noise (we consider Gaussian, Poisson, Gamma and Rayleigh) we propose a simple yet effective method to discriminate the noise model (or lack of) that corrupts the observed image by first applying a set of variance-stabilizing transforms and then proceed to estimate the variance using a local statistics estimator; the estimated variance will be unitary only for the particular variance-stabilizing transform that matches the correct noise model.

Session: MPa6 – Tensor-based Array Signal Processing

Chair: ***Martin Haardt,*** *Ilmenau University of Technology*

MP6a-1 1:30 PM

Modeling Latency and Shape Changes in Trial Based Neuroimaging Data

Morten Mørup, Technical University of Denmark; Kristoffer Hougaard Madsen, Hvidovre Hospital; Lars Kai Hansen, Technical University of Denmark

To overcome poor signal-to-noise ratios in neuroimaging, data sets are often acquired over repeated trials that form a three-way array of space x time x trials. Multi-linear decompositions can exploit consistency over trials and contrary to bi-linear decomposition render unique representations without additional constraints. Here we extend multi-linear decomposition to account for general temporal modeling within a sparse convolutional representation. We demonstrate how this alleviates degeneracy and helps to extract physiologically plausible components. The resulting convolutive multi-linear decomposition can model realistic trial variability as demonstrated in EEG and fMRI data. In order to estimate the model order and degree of sparsity within the convolutional representation we make use of automatic relevance determination (ARD).

MP6a-2 1:55 PM

Canonical Decomposition of Non-Negative arrays

Julie Coloigner, Laurent Albera, Lotfi Senhadji, Amar Kachenoura, University of RENNES 1, LTSI and INSERM, UMR 642

The semi-nonnegative INDSCAL decomposition is a special case of canonical decomposition. It consists in canonically decomposing a three-way array, which has two equal and nonnegative loading matrices. This problem has great interest in blind source separation, particularly in Magnetic Resonance Spectroscopy (MRS), where each observation spectrum is a nonnegative linear combination of different constituent spectra. In order to achieve the semi-nonnegative INDSCAL decomposition of a given three-way array, we propose a novel technique, which optimizes an unconstrained problem obtained by means of a square change of variable. The method is compared with other algorithms proposed at TDA'10 in terms of performance and numerical complexity on both random synthetic arrays and cumulant arrays estimated from synthetic MRS data.

MP6a-3 2:20 PM

Tensor-Based Semi-Blind Channel Estimation for MIMO OSTBC-Coded Systems

Florian Roemer, Ilmenau University of Technology; Nima Sarmadi, Technische Universität Darmstadt; Bin Song, Martin Haardt, Ilmenau University of Technology; Marius Pesavento, Alex Gershman, Technische Universität Darmstadt

We propose a novel semi-blind tensor-based MIMO channel estimation scheme that employs orthogonal space-time block codes and per-antenna power loading at the transmitter. Our scheme eliminates the unknown transmit codewords and constructs a tensor model that contains the channel coefficients by performing post-processing at the receiver. Then, the channel matrix has been found through appropriate tensor decompositions of the post-processed data. Since the inherent structure of the data model has been exploited, we obtain a more accurate channel estimate compared to previously devised matrix-based approaches. Further, introduced ambiguities have been resolved via additional pilot symbols in a semi-blind manner. Simulation results demonstrate performance improvements of our proposed tensor-based approach with respect to some current state-of-the-art semi-blind channel estimation schemes.

MP6a-4 2:45 PM

Tensor Decompositions with Block-Toeplitz Structure and Applications in Signal Processing

Mikael Sorensen, Lieven De Lathauwer, K.U. Leuven

Tensor decompositions with Toeplitz or block-Toeplitz structure are common in signal processing. For instance, they show up in blind system identification and deconvolution. We first present new uniqueness results, obtained by simultaneously taking the tensor nature and the block-Toeplitz structure of the problem into account. Second, we present numerical methods for computing a tensor decomposition with Toeplitz or block-Toeplitz structure.

Session: MPb6 – Compressive Sensing for Array Processing

Chair: ***Benjamin Friedlander,*** *University of California, Santa Cruz*

MP6b-1 3:30 PM

The MUSIC Algorithm for Compressive Imaging: Noise Stability and Performance Guarantee

Albert Fannjiang, University of California, Davis

The MUSIC algorithm is applied to support recovery of sparse (point or extended) objects and its performance is analyzed in the framework of compressed sensing (CS). Rigorous, quantitative conditions guaranteeing noisy stability are established in terms of restricted isometry property (RIP). An error bound is obtained for extended object imaging. As an essentially gridless method, the MUSIC algorithm is shown to possess the property of approximate support recovery in the presence of arbitrary, unresolved grids, an advantage not shared by standard CS methods such as the Basis Pursuit and the LASSO. Numerical examples are given.

MP6b-2 3:55 PM

Some Theoretical Results for Compressive Radar

Thomas Strohmer, University of California, Davis; Benjamin Friedlander, University of California, Santa Cruz

We present novel theoretical results for MIMO radar for the case where the observed scene is sparse. Using tools developed in compressive sensing, we derive bounds on the range-Doppler-azimuth resolution and the number of moving targets that can be recovered from noisy data. In particular, explicit conditions are presented for the transmit and receive arrays, the radar waveforms and the discretization of the range-Doppler-azimuth domain so that the radar sensing matrix has small coherence. By combining this result with the Least Absolute Shrinkage and Selection Operator (LASSO) we can ensure with high probability recovery of targets above the noise level. Our framework does not require any limitations on the dynamic range between targets.

MP6b-3 4:20 PM

Sensitivity Considerations in Compressed Sensing

Louis Scharf, Ali Pezeshki, Colorado State University; Yuejie Chi, Princeton University

We begin by asking whether there is anything of concern in the framing of nonlinear, overdetermined, parameter estimation problems in radar, sonar, and communication as linear, under-determined, sparse, compressed sensing problems. There is. We then study the sensitivity to basis mismatch of CS estimators for range, multi-path delay, Doppler, mode frequency, direction of arrival, etc. We aim to categorize problems by their sensitivity to basis mismatch and bound performance as a function of suitable measures of mismatch. In active sensing there may be a way to design for insensitivity and we intend to frame this question, if not illuminate it.

MP6b-4 4:45 PM

Coherence, Compressive Sensing and Random Sensor Arrays

Lawrence Carin, Duke University

Random sensor arrays are examined from a compressive sensing (CS) perspective, particularly in terms of the coherence of CS matrices. It is demonstrated that the maximum sidelobe level of an array corresponds to the coherence of interest for CS. This understanding is employed to explicitly quantify the accuracy of array source localization, as a function of the number of sources and the noise level. The analysis demonstrates that the CS theory is applicable to arrays in vacuum as well as in the presence of a surrounding linear media; further, the presence of a surrounding media with known properties may be used to improve array performance, with this related to phase conjugation and time reversal. Several numerical results are presented to demonstrate the theory.

Session: MPa7 – Processing of Physiological Signals

Co-Chairs: ***Nuri Firat Ince,*** *University of Minnesota* ***and Morten Morup,*** *Technical University of Denmark*

MP7a-1 1:30 PM

Does the Morphology of High-Frequency (100-500 Hz) Brain Oscillations Change During Epileptic Seizures?

Allison Pearce, Drausin Wulsin, Brian Litt, Justin Blanco, University of Pennsylvania

Transient high-frequency (100-500 Hz) oscillations (HFOs) recorded from the human brain are a potential biomarker for epileptogenic tissue. Whether the morphology of these events can be used to understand seizure generation is unknown. In this experiment, we used supervised learning in an attempt to distinguish HFOs occurring during versus outside of seizures in five patients implanted with intracranial electrodes. We trained three classifiers using logistic regression, k-nearest neighbors, and support vector machines and assessed their performance using the F1 score and permutation testing. All classifiers had low F1 scores, but two performed slightly better than chance in some patients. These results suggest that HFOs remain relatively consistent between ictal and interictal periods and a morphology change is unlikely to be associated with seizure generation.

MP7a-2 1:55 PM

Early Investigations into Subjective Audio Quality Assessment Using Brainwave Responses

Charles Creusere, Srikant Siddenki, New Mexico State University; Joe Hardin, Colorado State University; Jim Kroger, New Mexico State University

In this work, we take the first steps towards quantifying changes in the perceived quality of audio by directly measuring human subjective brainwave responses using a high-resolution electro-encephelogram (EEG). Specifically, human subjects are presented with audio whose quality varies with time while being monitored by a 128-channel EEG; some of the time, they move a slider bar up and down to indicate their perception of the changing quality while at other times they listen passively. Our focus here is to identify low-level features in the brainwave responses that correlate well with temporal quality variations across multiple base audio sequences and different test subjects.

MP7a-3 2:20 PM

Electrocardiogram Signal Modeling and Estimation Using the Interacting Multiple Model Particle Filtering

Shwetha Edla, Narayan Kovvali, Antonia Papandreou-Suppappola, Arizona State University

Modeling Electrocardiogram (ECG) signals is a task of great clinical importance as the model parameters can be utilized to classify between different kinds of heart diseases and monitor cardiac health. However, ECG signals consist of fiducial points with different morphologies (namely the P wave, QRS complex and the T wave) in a single heart beat, that can vary depending upon the person or disease state, and may not be described using a single representation. Also, existing statistical models for ECG depend upon user-specified parameters and \textit{a priori} information which requires a lot of pre-processing. In this paper, we propose a novel method for modeling ECG signals using the interacting multiple model (IMM) framework, which can adaptively choose between different representations depending upon the morphology of the ECG data. Our results use real ECG signals to demonstrate that the proposed model can accurately track different kinds of morphologies by choosing the most appropriate model at each time step without requiring large amounts of prior information about the signals.

MP7a-4 2:45 PM

A Novel Approach for Simulation, Measurement and Representation of Surface EMG (sEMG) Signals

Anvith Mahabalagiri, Khadeer Ahmed, Fred Schlereth, Syracuse University

In this paper, we describe new methods for the simulation, measurement and representation of SEMG signals. With regard to simulation, we choose a 2-D state space model and suggest a 3–D model which can account for inhomogeneities, nonlinearities and memory in the medium and which can be hardware accelerated through FPGA. With regard to measurement we use surface electrodes with a new amplifier circuit topology, which mitigates the effects of pickup and artifacts. With regard to representation, we describe a method for using wavelets which shows promise for isolating signals of interest.

Session: MPb7 – Model-based Design Optimization

Chair: ***Michael Schulte,*** *AMD*

MP7b-1 3:30 PM

Distributed Energy and Environment Sensing for Smart Building Management

Chen Xia, Hao Liu, Xiangrong Zhou, University of Hawaii

Electric energy consumption from residential and commercial buildings is one of the largest energy waste sources. In order to increase energy efficiency and integrate renewable energy sources to traditional buildings, it is critical to collect distributed energy consumption information and surrounding environment information. The paper presents a case study that uses wireless mesh network to sparsely collect real time energy and temperature information for a few sampling points in the building, and uses a factor graph model to generate estimated samples for other points. The results show that with the improvement of the model, significant sampling costs can be reduced.

MP7b-2 3:55 PM

FPGA-Accelerator System for Computing Biologically-Inspired Feature Extraction Models

Michael DeBole, Pennsylvania State University; Chi-li Yu, Arizona State University; Ahmed Al Maashri, Matthew Cotter, Pennsylvania State University; Chaitali Chakrabarti, Arizona State University; Vijaykrishnan Narayanan, Pennsylvania State University

Brain-inspired, or neuromorphic, algorithms for computer based vision and sensing provide an unprecedented improvement in the way digital systems can analyze and interpret information. However, for true biomimecry, implementations of neuromorphic algorithms must not only meet real-time performance goals, but also size, weight, and power (SWAP) constraints. FPGAs provide a customizable hardware platform for extracting maximum parallelism while maintaining low power consumption. The FPGA's reconfigurability provides excellent opportunities for algorithm-architecture co-exploration for emerging neuromorphic algorithms. In this work, a FPGA accelerator system for computing the HMAX cortical model is presented which is used to evaluate tradeoffs between algorithm performance, accuracy, and power.

MP7b-3 4:20 PM

A Machine Model for Dataflow Actors and its Applications

Jorn W. Janneck, Lund University

In application areas that process stream-like data (e.g. multimedia, networking, DSP), the pipelined concurrent processing is frequently represented as a dataflow network of communicating computational kernels called "actors", connected by FIFO queues. However, while dataflow is a natural medium for conceptualizing and modeling stream-processing systems, its adoption as a general programming methodology has been hindered by a an apparent choice between expressiveness and efficient implementability---very efficient implementation techniques being primarily limited to very restricted subclasses of dataflow programs. The paper presents a simple machine model for a very general class of dataflow actors and shows how it can be used as the foundation for the efficient implementation of a much broader range of dataflow programs.

MP7b-4 4:45 PM

Operation Set Customization in Retargetable Compilers

Heikki Kultala, Pekka Jääskeläinen, Mikael Lepistö, Jarmo Takala, Tampere University of Technology

The core tool in application-specific instruction set (ASIP) processor design toolsets is a retargetable compiler, which can generate efficient code to any processor developed with the toolset. Such a compiler must automatically adapt itself to the operation set supported by the designed processor by emulating missing instructions with other instructions and by selecting custom instructions automatically whenever possible. This paper proposes a simplified DAG-based recursive mechanism to support operation set customization. The proposed mechanism is capable of generating instruction selectors and architecture simulation models automatically, thus is suitable for fast design space exploration of ASIP operation sets.

Session: MPa8 – Adaptive Filtering 1:30 PM – 3:10 PM

Chair: ***Andrew Klein,*** *Worcester Polytechnic Institute*

MP8a1-1
Simplified Complex LMS Algorithm for the Cancellation of Second-Order TX Intermodulation Distortions in Homodyne Receivers

Christian Lederer, Mario Huemer, Alpen-Adria-Universitaet Klagenfurt

Intermodulation distortions are produced by a modulated blocker signal with a non-constant envelope travelling through non-linear analog stages. Especially in homodyne receivers (RX) the second-order intermodulation distortions (IMD2) are problematic since they overlay the wanted RX baseband signal. In this paper an approach to cancel the transmitter (TX) induced IMD2 in the digital domain is presented. Furthermore, it is shown that the cancellation of IMD2 can be performed independently for the in-phase (I) and quadrature (Q) component of the complex RX baseband signal. The performance of the proposed cancellation approach is verified on measured RX data of a UMTS transceiver chip.

MP8a1-2
A Steady-State Analysis of the E-Normalized Sign-Error Least Mean Square (NSLMS) Adaptive Algorithm

Mohammed Faiz, Azzedine Zerguine, King Fahd University of Petroleum & Minerals

In this work, expressions are derived for the steady-state excess-mean-square error (EMSE) of the e¡normalized sign-error least mean square (NSLMS) adaptive algorithm for both cases of real- and complex-valued data. Moreover, a comparison between the computational load of the e-NSLMS algorithm and the e¡normalized least mean square (NLMS) algorithm is also presented. Finally, simulation results to substantiate the theoretical findings are presented.

MP8a1-3
A Modified Non-Negative LMS Algorithm and its Stochastic Behavior Analysis

Jie Chen, Cédric Richard, Université de Nice Sophia-Antipolis; Jose Bermudez, Federal University of Santa Catarina; Paul Honeine, Université de Technologie de Troyes

Dynamic system modeling plays a crucial role in the development of techniques for stationary and non-stationary signal processing. Due to the inherent physical characteristics of systems under investigation, non-negativity is a desired constraint that can usually be imposed on the parameters to estimate. Nonnegative LMS (NN-LMS) algorithm is an efficient adaptive algorithm that has recently been proposed in the literature. During convergence of NN-LMS algorithm, it has however been observed that weights may have different convergence rates and accuracy, especially those in the active set. In this paper we introduce a modified NN-LMS algorithm in order to alleviate these unbalanced convergence rates. We also propose analytical models to characterize the stochastic behavior of this algorithm.

MP8a1-4
A Robust LMS Adaptive Algorithm over Distributed Networks

Muhammad Bin Saeed, Azzedine Zerguine, Salam Zummo, King Fahd University of Petroleum & Minerals

This work studies the effect of erroneous noise power estimates on the behavior of a noise constrained diffusion-based adaptive algorithm for distributed adaptive networks. For good performance, the noise constrained diffusion least mean square (NCDLMS) algorithm assumes knowledge of the noise variance is available at each node. In this work, it is shown that the NCDLMS algorithm is robust to large variations in noise variance estimation. Moreover, the mean and steady-state analyses of the NCDLMS algorithm are carried out and simulation results are found to corroborate the theoretical findings. Great improvement in performance is obtained through the use of the proposed algorithm even when no information on the noise variance is available. The increased computational complexity of the NCDLMS algorithm is justified through the performance improvement it offers.

MP8a1-5
Error-Based “Gear-Shifting” for a Generalized LMS Algorithm

John J. Shynk, University of California, Santa Barbara

The generalized least-mean-square (LMS) adaptive algorithm recursively minimizes the instantaneous error |e(k)|^r where r is any real number >= 1. In most implementations of the LMS algorithm, the error cost function is fixed and the step-size parameter mu > 0 is sometimes varied to improve the convergence rate. In this paper, we maintain a fixed mu and instead vary r during

the adaptation process. We find that this "gear-shifting" allows for fast adaptation when |e(k)| > 1, and then the algorithm can be slowed down when |e(k)| << 1 to reduce the steady-state misadjustment. If the signals become nonstationary, the proposed algorithm automatically "changes gears" to rapidly track such changes until slower adaptation is again needed to minimize fluctuations about the desired solution.

MP8a1-6
A Variable Step-Size GMDF and its Performance Analysis
Hsu-Chang Huang, Junghsi Lee, Yuan-Ze University

Numerous time-domain variable step-size normalized least mean square algorithms have been derived to solve the dilemma of fast convergence rate or low excess mean-square error in the past two decades. This paper proposes a variable step-size control method for the generalized frequency-domain multidelay adaptive filter (GMDF), which is an attractive choice in applications requiring a large number of coefficients such as acoustic echo cancellation. This algorithm employs the mean-square error and the estimated system noise power to control the step-size update in each frequency bin. Simulation experiments show our algorithm performs very well. Furthermore, the theoretical steady-state behavior is in very good agreement with the experimental results

MP8a1-7
Acoustic Feedback and Echo Cancellation Strategies for Multiple-Microphone and Single-Loudspeaker Systems
Meng Guo, Thomas Bo Elmedyb, Oticon A/S; Søren Holdt Jensen, Aalborg University; Jesper Jensen, Oticon A/S

Acoustic feedback/echo cancellation in a multiple-microphone and single-loudspeaker system is often carried out using a cancellation filter for each microphone channel, and the filters are adaptively estimated, independently of each other. In this work, we consider another strategy by estimating all filters jointly. We determine the statistical system behavior for the joint estimation strategy in terms of the convergence rate and steady-state behavior across time and frequency. We assess if an improved cancellation performance is achievable compared to the independent estimation strategy. Furthermore, we relate the joint estimation strategy to a stereophonic acoustic echo cancellation system and provide analytic expressions for its system behavior.

MP8a1-8
Comparison of Several Techniques for Adaptive Band-Stop Filters
Michael Soderstrand, University of California (Retired)

Adaptive band-stop filters used for attenuation of narrow-band interference in spread-spectrum receivers or due to resonances in control systems and instrumentation are becoming more common as we pack more signals into limited bandwidth. Two techniques for implementing these adaptive band-stop filters include adaptive heterodyne filters and adaptive filters based on pre-stored filter coefficients. Simulations show that adaptive heterodyne filters have strong advantages in the case of high-speed applications particularly when the band-stop filter requires many taps with the pre-stored coefficient technique having advantages in low-speed applications and applications that can be achieved with a small number of filter taps.

Track H. Speech, Image and Video Processing
Session: MPa8 – Speech Processing, Recognition and Coding 1:30 PM – 3:10 PM
Chair: ***Jerry Gibson,*** *University of California, Santa Barbara*

MP8a2-1
Automatic Phoneme Recognition with Segmental Hidden Markov Models
Areg Baghdasaryan, A. A. (Louis) Beex, Virginia Polytechnic Institute and State University

A new technique is presented for the joint recognition and segmentation task formulated for a speaker independent continuous phoneme recognition and segmentation system. We investigate a strictly probabilistic approach for simultaneous phoneme sequence segmentation and recognition. The implemented automatic phoneme recognition system integrates phoneme length statistics as well as phoneme transition statistics into the Segmental Hidden Markov Model (SHMM). A variation of the Viterbi Search algorithm is employed for estimating the most likely sequence of phonetic symbols as well as their corresponding segment boundaries. The Segmental HMM topology essentially models a phonetic symbol string with a double layer Hidden Markov Model (HMM), with each phonetic symbol in the Segmental HMM modeled with a left-to-right HMM. Our approach lays the groundwork for further expansion of Segmental HMM design to context dependent continuous phoneme recognition systems.

MP8a2-2
A Perceptually Re-Weighted Mixed-Norm Method for Sparse Approximation of Audio Signals
Mads Christensen, Bob Sturm, Aalborg University

In this paper, we consider the problem of finding sparse representations of audio signals for coding purposes. In doing so, it is of utmost importance that when only a subset of the present components of an audio signal are extracted it is the perceptually most important ones. To this end, we propose a new iterative algorithm based on two principles: 1) a reweighted 1-norm based measure of sparsity; and 2) a reweighted 2-norm based measure of perceptual distortion. Using these measures, the considered problem is posed as a constrained convex optimization problem that can be solved optimally using standard software. A prominent feature of the new method is that it solves a problem that is closely related to the objective of coding, namely rate-distortion optimization. In computer simulations, we demonstrate the properties of the algorithm and its application to real audio signals.

MP8a2-3
Scalable Multimode Tree Coder with Perceptual Pre-Weighting and Post-Weighting for Wideband Speech Coding
Ying-Yi Li, Jerry Gibson, University of California, Santa Barbara

A scalable Multimode Tree Coder with perceptual pre-weighting and post-weighting filters for wideband speech is presented. The average bit-rate of the Mutlimode Tree Coder operates at 40%-75% of the bit-rate of G.722 for equivalent WPESQ. In addition, the algorithmic delay is 12.375 ms, which is about half of AMR-WB, and computational complexity of the Multimode Tree Coder is about a third of AMR-WB. Therefore, the Multimode Tree Coder is a low delay, low complexity, and moderate bit-rate speech codec for wideband speech. The scalable wideband Multimode Tree Coder provides a variable bit rate operation not available before, while maintaining good performance, low delay, and low complexity.

MP8a2-4
Isolated Word Endpoint Detection Using Time-Frequency Variance Kernels
Alexandros Kyriakides, Costas Pitris, University of Cyprus; Andreas Spanias, Arizona State University

A major challenge in developing endpoint detection systems is the presence of background noise. We have developed a hybrid method for performing endpoint detection which is based on spectrogram estimation using LPC and a detection process based on imaging operations on the spectrogram. We found that this hybrid approach to endpoint detection is robust to various types and levels of background noise. High-variance regions in the spectrogram, captured by variance kernels, can be used to accurately determine the endpoints of speech. We compared our results with various state-of-the-art methods and we found several cases where our approach compares favorably.

MP8a2-5
Performance Enhanced Multi-Rate iLBC
Koji Seto, Tokunbo Ogunfunmi, Santa Clara University

The Internet Low Bit-rate Codec (iLBC) features high robustness to packet loss through frame-independent coding. The multi-rate flexibility was added to the iLBC using the Discrete Cosine Transform (DCT) by our previous work. In this work, the various approaches to improve the performance are presented. The experimental results show that the performance improvements are observed at all the bit rates despite the fact that the memory requirements are reduced.

MP8a2-6
Enabling Improved Speaker Recognition by Voice Quality Estimation
Anthony Bartos, Welkin Associates, Ltd.; Douglas Nelson, U.S. Department of Defense

Presented is a method to mitigate noise and interference in automated speaker identification (SID). In this process, speaker models are built for a lattice of signal to noise ratio (SNR) levels. Speech activity detection is applied to identify portions of the signal that contain speech, and the SNR is blindly estimated. Speaker models representing the SNR of the received signal are dynamically loaded, and conventional SID is applied. In training, the SNR of each training signal is estimated, and the signal is modified by adding noise to create a signal at the desired SNR. Using this process, each signal may be used to train models at any SNR level less than or equal to the SNR of the original signal. The process has been fully implemented and is completely automated.

Session: MPa8 – Parameter Estimation 1:30 PM – 3:10 PM

Chair: ***P.P. Vaidyanathan,*** *California Institute of Technology*

MP8a3-1

On Spatial Smoothing of High Resolution Direction Finding of Real-Valued Sinusoidal Signals

H. Howard Fan, University of Cincinnati; Stewart DeVilbiss, Air Force Research Laboratory

Spatial smoothing is a well-known method for high-resolution direction estimation, such as the MUSIC algorithm, of coherent sources. This method, however, was designed for complex-valued sinusoidal sources. In this paper we show that this spatial smoothing method equally applies to real-valued sinusoidal signal sources. A theoretical derivation as well as computer simulations are provided in this paper.

MP8a3-2

Non-Uniform Linear Arrays for Improved Identifiability in Cumulant Based DOA Estimation

Piya Pal, P. P. Vaidyanathan, California Institute of Technology

Direction of arrival (DOA) estimation methods based on arbitrary even order (2q, q>= 2) cumulants of the received data are known to be capable of identifying many more non Gaussian sources (O(N^{q})) than the physical number (N) of sensors. However, in this paper, it is shown that the identifiability of 2qth order cumulant based DOA estimation can be significantly higher than this. This is due to the fundamental connection of the 2qth order cumulants with the concept of a 2qth order difference co-array, which is a virtual array determined solely by the physical array geometry. Depending on the sensor orientations, the 2qth order difference co-array can contain as many as O(N^{2q}) elements. In order to find a class of linear physical arrays which achieves this, a new generic class of non uniform linear arrays, namely the 2qth order nested array, is proposed, whose 2qth order difference co-array is proved to contain an uniform linear array (ULA) segment with O(N^{2q}) sensors. Also, to exploit these increased degrees of freedom of the co-array, a new algorithm for DOA estimation is developed, which starts from the same 2qth order cumulant matrix as the earlier methods and can yet identify O(N^{2q}) sources.

MP8a3-3

Knowledge-Aided Direction Finding Based on Unitary ESPRIT

Jens Steinwandt, Ilmenau University of Technology; Rodrigo C. de Lamare, University of York; Martin Haardt, Ilmenau University of Technology

In certain applications involving direction finding, a priori knowledge of a subset of the directions to be estimated is sometimes available. Existing knowledge-aided (KA) methods apply projection and polynomial rooting techniques to exploit this information. In this paper, a new strategy for incorporating prior knowledge in situations with a limited data record based on the Unitary ESPRIT algorithm is developed. The proposed Unitary KA-ESPRIT algorithm processes an enhanced covariance matrix estimate obtained by linearly combining the sample covariance matrix and a prior known covariance matrix in an automatic fashion. Simulations show that the derived algorithm substantially improves the estimation accuracy of the unknown signal directions.

MP8a3-4

Maximum Likelihood Time Delay Estimation for CDMA Direct-Spread Multipath Transmissions Using Importance Sampling

Ahmed Masmoudi, Faouzi Bellili, Sofiene Affes, INRS-EMT

In this paper, we address the problem of time delay estimation for Direct-Spread CDMA multipath transmissions. We observe that the attractive post-correlation model (PCM) of the despread data allows for exploiting results provided in array signal processing and we introduce a new time delay estimator based on the maximum likelihood (ML) criterion. The new technique finds the global maximum of the compressed likelihood function in an efficient way using the importance sampling (IS) technique. Simulation results show that the new estimator provides very good performance in challenging cases of very closely-spaced delays even with a few receiving antenna branches. The Cramer-Rao lower bound (CRLB) for multipath delays is also provided.

MP8a3-5
Particle Filter Based DOA Estimation for Multiple Source Tracking (MUST)
Thomas Wiese, Technical University Munich; Heiko Claussen, Justinian Rosca, Siemens Corporation, Corporate Research

Direction of arrival estimation is a well researched topic and represents an important building block for higher level interpretation of data. The Bayesian algorithm proposed in this paper (MUST) can estimate and track the direction of multiple, possibly correlated, wideband sources. MUST approximates the posterior probability density function of the source directions in time-frequency domain with a particle filter. In contrast to other previous algorithms, no time-averaging is necessary, therefore moving sources can be tracked. MUST uses a new low complexity weighting and regularization scheme to fuse information from different frequencies and to overcome the problem of overfitting when few sensors are available.

MP8a3-6
Direction-of-Arrival Estimation Using Distributed Body Area Networks: Error & Refraction Analysis
Kaveh Ghaboosi, Pranay Pratap Swar, Kaveh Pahlavan, Worcester Polytechnic Institute

In this paper, we investigate Direction Of Arrival (DOA) estimation using Body Area Networks (BANs), consisting of two independent yet cooperative distributed sensor arrays, i.e., body mounted measurement devices and in-body sensory implants. Following a canonical coordinate perspective, the impact of localization error due to body surface movement and sensor devices random displacement is taken into account when formulating the problem. We begin with a two-dimensional deployment scenario and extend existing studies to incorporate localization error and subsequently, a realistic three-dimensional sensor network configuration comprising two sets of distributed devices is considered. While the former assumes that the sensor nodes are placed on a plane parallel to the normal vector of the arriving electromagnetic front wave, the latter considers a general network topology, where sensors are either randomly placed on a given plane or in the half-space below the plane. For the three-dimensional scenario, we obtain array steering vectors for different sets of sensors and study the impact of incoming wave diffraction due to entrance to the human body. Accounting realistic limited array size and sample support evaluation, we assess the performance of DOA estimation of multiple far-field narrow-band sources using distributed BANs under Canonical Correlation Analysis (CCA) framework.

MP8a3-7
Bayesian Estimation of a Subspace
Olivier Besson, University of Toulouse-ISAE; Nicolas Dobigeon, Jean-Yves Tourneret, University of Toulouse-IRIT/ENSEIHT

We consider the problem of subspace estimation in a Bayesian setting. First, we revisit the conventional minimum mean square error (MSE) estimator and explain why the MSE criterion may not be fully suitable when operating in the Grassmann manifold. As an alternative, we propose to carry out subspace estimation by minimizing the mean square distance (MSD) between the true subspace $\U$ and its estimate, where the considered distance is a natural metric in the Grassmann manifold. We show that the resulting estimator is no longer the posterior mean of $\U$ but entails computing the principal eigenvectors of the posterior mean of $\U \U^{T}$. Illustrative examples involving a linear Gaussian model for the data and a Bingham or von Mises Fisher prior distribution for $\U$ are presented. The method is shown to provide accurate estimates even when the number of samples is lower than the dimension of $\U$. An application to hyperspectral imagery is also presented.

MP8a3-8
Model Order Selection in Sensor Array Response Modeling
Mário Costa, Andreas Richter, Visa Koivunen, Aalto University

In this paper, a method for order selection needed in array response modeling using calibration data is proposed. It allows finding the optimal number of basis functions for describing the array steering vectors. Moreover, it facilitates denoising of array calibration measurements. The manifold separation principle is employed since it yields an orthogonal decomposition of the array steering vector regardless of the array nonidealities. Bayesian information criterion (BIC) as well as the more recent exponentially embedded family (EEF) and normalized minimum description length (nMDL) methods are extended to choosing the optimal number of modes in the orthogonal decomposition of the array steering vector. Extensive simulations using a real-world antenna array are included. The results illustrate that the nMDL is a consistent estimator of the optimal number of modes and has a performance close to the minimum mean-squared error.

Session: MPa8 – DSP Algorithms and Architectures 1:30 PM – 3:10 PM

Chair: ***Michael Schulte,*** *AMD, USA*

MP8a4-1

High Dynamic Range Adaptive Delta-Sigma Based Focal Plane Array Architecture

Shun Yao, Marvel Semiconductors; Sam Kavusi, Khaled Nabil Salama, King Abdullah University of Science and Technology

In this paper, an Adaptive Delta-Sigma based architecture for High Dynamic Range (HDR) Focal Plane Arrays is presented. The noise shaping effect of the Delta-Sigma modulation in the low end, and the distortion noise induced in the high end of Photo-diode current were analyzed in detail. The proposed architecture can extend the Dynamic Range (DR) about 20N log 2 dB at the high end of Photo-diode current with an N bit Up-Down counter. At the low end, it can compensate for the larger readout noise by employing Extended Counting. The Adaptive Delta-Sigma architecture employing a 4-bit Up-Down counter achieved about 160dB in the DR, with a Peak SNR (PSNR) of 80dB at the high end. Compared to the other HDR architectures, the Adaptive Delta-Sigma based architecture provides the widest DR with the best SNR performance in the extended range.

MP8a4-2

Block Circular and Hyperbolic Transformations for the Block Fast Array RLS Algorithm

Roger West, Todd Moon, Jacob (Jake) Gunther, Utah State University

Both circular and hyperbolic transformations are needed in the scalar fast array RLS (FARLS) algorithm to transform the pre-array into the post-array. These transformations ‘compress’ (in a J-unitary sense) the energy of the first column of the pre-array into the first entry of the post-array. Analogous transformations are needed in the block FARLS (BFARLS), except that the transformations need to ‘compress’ the energy of certain block matrices of the pre-array into the first square block of the post-array. A stable J-unitary block reflector is developed in this paper for transforming the pre-array into the post-array for the BFARLS algorithm.

MP8a4-3

The Polyphase Random Demodulator for Wideband Compressive Sensing

J.P. Slavinsky, Jason N. Laska, Richard Baraniuk, Rice University

Compressive sensing (CS) provides a mathematical platform for designing analog-to-digital converters (ADCs) that sample signals at sub-Nyquist rates. In particular, the frame- work espouses a linear sensing system and non-linear, iterative computational recovery algorithms. A central problem within this framework is the design of practical hardware systems that can be easily calibrated and coupled with computational recovery algorithms. In this paper, we propose a new CS-ADC that resolves some of the practical issues present in prior work. We dub this new system the polyphase random demodulator.

MP8a4-4

A Floating-Point Fused FFT Butterfly Arithmetic Unit with Merged Multiple-Constant Multipliers

Jae Hong Min, Seong-Wan Kim, Earl Swartzlander, The University of Texas at Austin

Abstract - This paper examines a low-power consumption 1024 point floating-point fused FFT realized with a Multiple-Constant Multiplier (MCM) and with a Merged Multiple-Constant Multiplier (MMCM). The FFT is constructed using Radix-2 butterfly operations that are implemented with MCMs and with MMCMs to reduce the power consumption and area. Conventional MCMs perform the significand multiplication, but with relatively low precision. To enhance the precision, a new architecture of the butterfly unit has been designed and implemented with MMCMs. The new architecture reduces the error by 65% compared to fused butterfly unit with MCMs at a slight cost in area and power consumption.

MP8a4-5

Exploiting Cross-Channel Quantizer Error Correlation in Time-Interleaved Analog-to-Digital Converters

Joseph G. McMichael, Shay Maymon, Alan V. Oppenheim, Massachusetts Institute of Technology

Uniform quantizers are often modeled as additive uncorrelated noise sources. This paper explores the validity of the additive noise model in the environment of time-interleaved A/D converters. Cross-channel quantizer error correlation is an important discrepancy that arises for channel timing delays in close proximity. It is demonstrated through simulation that negative

error correlation occurs for different granularity quantizers in close proximity. Statistical analysis is presented to characterize error correlation between different granularity quantizers operating at the same sampling instant. A technique exploiting this correlation often yields significant performance gains above the optimal additive noise model solution.

Track G. Architecture and Implementation

Session: MPa8 – Novel DSP Architectures 1:30 PM – 3:10 PM

Chair: ***David Thomas,*** *Imperial College London, UK*

MP8a5-1

In-Service Reconfiguration of Signal Processing Components

Gordon Brebner, Christopher Neely, Shay Seng, Xilinx, Inc.

Block-based design methodologies are common for building dataflow systems. However, after mapping to FPGA implementation, the original block structure is usually lost. Thus if run-time reconfiguration of the FPGA is to be used, it is necessary to have knowledge of the physical floorplan of a system on the FPGA and work in terms of it. In this paper, a novel methodology is introduced, whereby the original block diagram is preserved at run time, and so signal processing components can be changed or replaced in terms of the original dataflow design.

MP8a5-2

Rethinking Computation Using FPGA Based Accelerators for Large Applications

Dennis Allison, Michael J Flynn, Oskar Mencer, Maxeler Technologies

High Performance Computing, basically large clusters, does not scale to the level required for many real-world problems. At Maxeler, we have championed the idea of accelerators, hardware and software add-ons that help supercomputers run faster. A number of acceleration approaches are possible—muiti-core, many-core, GPUs, and FPGAs. We have found FPGAs work best. Given the initial area-time-power disadvantage of the FPGA compared to (say) a custom designed adder this is a surprising result. The sheer magnitude of the available FPGA parallelism overcomes the initial disadvantage. For large, monolithic applications (more than 1020 operations per run or continuously running) of interest we first identify the locus of dynamic activity (loosely termed the “kernels”). This is assigned to the accelerator. Next, where possible, the relevant program is configured as a streaming computation, with static instruction flow graph activated by the data stream.. Using the FPGA technology it’s possible to configure this data flow graph into a synchronous data flow machine to execute the computation. The array is synchronized to accept a new set of input arguments each cycle, spanning a pipeline of up to 500 stages. As an example we consider modeling problems in geophysics. In a typical problem we realize a 2000 node array on 2 FPGA’s, with a resulting 50- 100 times speedup over a conventional multicore server

MP8a5-3

Versatile FPGA DSP Blocks with Carry-Save Arithmetic Support

Hadi Parandeh Afshar, Paolo Ienne, École Polytechnique Fédérale de Lausanne (EPFL)

The selective use of carry-save arithmetic, where appropriate, can accelerate a variety of arithmetic dominated circuits. Carry-save arithmetic operations, such as multi-input addition (e.g., add $k > 2$ integers), occur naturally in many DSP applications and further opportunities to exploit them can be exposed through systematic dataflow transformations that can be applied by a hardware compiler. FPGAs, however, are not particularly well-suited to carry-save arithmetic. In theory, the adder trees contained within the multipliers of FPGAs DSP blocks could implement multi-input addition; however, they are not exposed to the programmer. In this paper, we will present new architectures for the DSP blocks to support carry save arithmetic. This will make the current FPGA DSP blocks more versatile and a much wider range of applications could benefit from the DSP blocks. Moreover, having the flexibility of adding different operands with different bit-widths reduces the cost of supporting different multiplier configurations within the DSP block.

MP8a5-4

Scalable Acceleration of High-Performance, Fourier-Domain Optical Coherence Tomography

Lesley Shannon, Simon Fraser University

Fourier Domain Optical Coherence Tomography (FD-OCT) is an emerging biomedical imaging technology featuring ultra-high resolution and fast imaging speed. Due to the complexity of the FD-OCT algorithm, real time FD-OCT imaging demands high performance computing platforms. However, the scaling of real-time FD-OCT processing for increasing data acquisition rates and 3-dimensional (3D) imaging is quickly outpacing the performance of general purpose processors. Our research analyzes the scalability of accelerating FD-OCT processing on two potential implementation platforms: General Purpose Graphical Processing Units (GPGPUs) and Field Programmable Gate Arrays (FPGAs). We implemented a complete FD-OCT system using a NVIDIA

GPGPU as co-processor, with a speed up of 6.9x over general purpose processors (GPPs). We also created a hardware processing engine using FPGAs with a speed up of 15.5x over GPPs for a single pipeline, which can be replicated to further increase performance. Our analysis of the performance and scalability for both platforms shows that, while GPGPUs offer an easy and low cost solution for accelerating FD-OCT, FPGAs are more likely to match the long term demands for real-time, 3D, FD-OCT imaging.

MP8a5-5
Fine-Grain Reconfigurable Functional Unit for Embedded Processors

Gian Carlo Cardarilli, Luca Di Nunzio, Rocco Fazzolari, Marco Re, University of Rome Tor Vergata

The execution of operations on data shorter than the native wordlength usually decreases the performance of standard microprocessors. In order to overcome this issue, various methods, based on reconfigurable structures, have been presented in the literature. These structures are normally realized as an array of elementary reconfigurable cells. A common solution for the realization of elementary reconfigurable cells is that based on Look-Up Tables. We propose a new Reconfigurable Functional Unit (RFU) based on full adders and reprogrammable interconnects named ADAPTO. The final aim is to obtain a new structure that, paying the price of slightly reduced flexibility, requires less silicon area and power, being ever faster than the ”traditional” solution. In this paper, we present the main characteristics of the proposed structure evaluating its performance (in terms of speed-up and power consumption) when integrated in an embedded processor.

MP8a5-6
Increasing Productivity of Reconfigurable Computing for Signal Processing

Wayne Luk, Imperial College London

Reconfigurable computing, which exploits reconfigurable hardware technologies such as field-programmable gate arrays, has been with us for at least two decades. Many promises of Reconfigurable Computing for signal processing, such as those concerning capabilities and costs, have been fulfilled. However, there remain promises of Reconfigurable Computing, such as those involving efficiency and productivity, which seem largely unfulfilled. This paper briefly reviews the progress of Reconfigurable Computing for the last 20 years, and suggests some promising directions for increasing the efficiency and productivity of reconfigurable DSP using high level languages, while maintaining the performance of low-level implementations.

MP8a5-7
Synchronous and Asynchronous Computations with Molecular Reactions

Hua Jiang, Marc D. Riedel, Keshab K. Parh Parhi, University of Minnesota

Molecular reactions will be used to perform iterative and sequential computations in synchronous as well as asynchronous manner. A clock generation scheme and a flipflop design will enable synchronous computations while an RGB scheme enables asynchronous computation. Examples from digital signal processing will be used.

MP8a5-8
Design and Implementation of a Flexible Queue Manager for Next Generation Networks

Qi Zhang, Roger Woods, Alan Marshall, Queen’s University Belfast

Next Generation Networks implies the need for new types of network managers. One approach creates a scalable, distributed Traffic Manager (TM) that can be programmed on demand. The core component is an efficient Queue Manager (QM) which is typically proprietary and costly. In this paper, a new QM architecture is given which is scalable and can adapt to changing network conditions. The design and implementation using current FPGA technology is outlined; performance and area figures are included as well as details of the implementation on the recently announced, NetFPGA-10G development board.

Track B. MIMO Communications and Signal Processing

Session: TAa1 – Random Matrices in Signal Processing and MIMO Communications

Chair: ***Matthew McKay,*** *Hong Kong University of Science and Technology*

TA1a-1 8:15 AM

Beyond Eckart-Young-Mirsky: Exploiting Random Matrix Theory to Improve Subspace Approximation

Raj Rao Nadakuditi, University of Michigan

We consider an signal matrix (or subspace) estimation problem where we have a signal-plus-noise measurement matrix that is modeled as the sum of a rank-k signal matrix and an isotropically random noise-only matrix. We exploit recent results from random matrix theory to develop a data-driven algorithm that treats the singular value decomposition (SVD) of the signal-plus-noise measurement matrix as a noisy SVD and optimally post-filters it to improve the signal matrix approximation error. We explain why we are able to obtain this improvement relative to the Eckart-Young-Mirsky theorem motivated “optimal” approximation using the rank-k SVD of the noisy measurement matrix.

TA1a-2 8:40 AM

Beyond IID Gaussian Matrices in Compressed Sensing

Antonia Tulino, Bell Laboratories, Alcatel-Lucent; Giuseppe Caire, University of Southern California; Shlomo Shamai, Technion-Israel Institute of Technology; Sergio Verdú, Princeton University

Consider a Bernoulli-Gaussian vector whose components are xiBi, with Bi Bernoulli-q and xi \sim CN(0; \sigma^2), i.i.d. across i and mutually independent. This randomly nulled vector is multiplied by a random matrix U, and a randomly chosen subset of the components of the resulting vector is then observed in additive Gaussian noise. We extend the scope of conventional models where U is typically the identity or a matrix with iid components, to allow U that satisfies a certain freeness condition, which encompasses Haar matrices and other unitarily invariant matrices. We use the replica method and the decoupling principle of Guo-Verd´u, as well as a number of information theoretic bounds, to study the input-output mutual information and the support recovery error rate.

TA1a-3 9:05 AM

Mutual Information Distribution of Interference-Limited MIMO: A Joint Coulomb Fluid and Painlevel Based Approach

Shang Li, Hong Kong University of Science and Technology; Yang Chen, Imperial College London; Matthew McKay, Hong Kong University of Science and Technology

This paper investigates the mutual information distribution of interference-limited multiple-input multiple-output channels. We further develop our recent work [1], where an exact expression was derived for the moment generating function in terms of a Painlev\'{e} VI differential equation, along with a Gaussian approximation based on the Coulomb fluid method. In this paper, we adopt a framework based on appropriately combining these results to obtain insight into the distributional behavior. First, we demonstrate that the Coulomb fluid approximation is in fact exact to leading order in the number of antennas, thereby yielding the correct asymptotic mean and variance. We then compute closed-form expressions for the first-order correction terms to the mean and variance, as well as expressions for the third cumulant. These results provide valuable insight into the ``Gaussianity'' of the mutual information distribution, indicating how the deviations from Gaussian are affected by parameters such as the signal-to-interference-ratio and the number of interferers.

TA1a-4 9:30 AM

Outage Capacity for MIMO-OFDM Systems in Block Fading Channels

Marco Chiani, University of Bologna; Andrea Conti, University of Ferrara; Matteo Mazzotti, Enrico Paolini, University of Bologna; Alberto Zanella, WiLab/IEIIT-BO CNR

We introduce the concept of outage capacity for MIMO-OFDM systems for channels characterized by block fading in both time and frequency domains. The outage is shown to be related to the characteristic function of the capacity for the usual quasi-static MIMO fading channel case. We also compare the outage capacity with the performance of MIMO-OFDM employing powerful error correcting codes based on LDPC when, due to finite frequency or time interleaving, there is only a small number of fading blocks per codeword.

Session: TAb1 – Biosignal Estimation and Classification

Co-Chairs: ***Ulisses Braga-Neto,*** *Texas A&M University* ***and Antonia Papandreou-Suppappola,*** *Arizona State University*

TA1b-1 10:15 AM

A Real-Time Reconstruction Algorithm for the Integrate and Fire Sampler

Alexander Singh Alvarado, Jose Principe, University of Florida

We provide a real-time recovery algorithm from the Integrate and Fire (IF) sampler. This event-based sampler provides compression for signals whose relevant features are localized in time and amplitude. In this paper we use the sampler to encode neural action potentials in state-of-the-art Brain Machine Interfaces (BMI). Our previous approach was based on methods from frame-theory and nonuniform sampling. In this paper we propose a cubic spline model for neural data and an online recovery algorithm. The performance of the decoding scheme is based on a tradeoff between data-rates and detection and clustering of the neural action potentials.

TA1b-2 10:40 AM

Using Physiological Signals to Predict Apnea in Preterm Infants

James Williamson, Daniel Bliss, David Browne, MIT Lincoln Laboratory; Elisabeth Salisbury, Premananda Indic, David Paydarfar, University of Massachusetts Medical School

Apnea of prematurity, a pervasive developmental disorder in preterm infants, is implicated in long-term neurodevelopmental deficits. Preventative clinical interventions, such as mechanosensory stimulation, would benefit from predictive knowledge of when the patient is at high risk for apnea. A patient-specific apnea prediction algorithm is proposed and evaluated on recordings from several preterm infants. The algorithm extracts correlational and information-theoretic features from multiple physiological signals by using a patient-specific classifier and state transition model to detect when the patient is at high risk for apnea and its associated negative consequences of bradycardia and hypoxemia.

TA1b-3 11:05 AM

Assessing Dysarthria Severity Using Global Statistics and Boosting

Alicia DeMino, General Dynamics; Robert Kubichek, University of Wyoming; Kevin Caves, Duke University

A new method for automatic assessment of Dysarthria severity is described. It uses the forward selection method (FSM) on global statistics of low-complexity features to find effective feature sets. FSM is embedded in a boosting algorithm that combines multiple weak classifiers to achieve a single strong classifier. Unlike standard boosting, this uses nonlinear class boundaries and unique feature sets per iteration. Results on a 39 speaker dysarthria database are described.

TA1b-4 11:30 AM

Characterization of Human Use of Ethanol Based on Video Games with Ethanol Rewards: Model, System Identification and Statistical Performance

Ipek Ozil, Cornell University; Martin H. Plawecki, Indiana University School of Medicine; Peter C. Doerschuk, Cornell University; Sean J. O'Connor, Indiana University School of Medicine

Recent research on alcoholism explores the influence of family history and genetics on the risk of developing abuse or dependence. Endophenotypes and behavioral paradigms have been used to help detect genetic contributions to this disease. Electronic tasks, which can be considered video games, that provide alcohol as a reward in controlled environments have been developed to explore some of the behaviors and characteristics of individuals with or at risk for alcohol substance use disorders. One such game involves a progressive work paradigm where subjects receive larger or smaller alcohol rewards for completing the task. A generative model for this game is described along with the signal processing needed to characterize the subjects' behavior by system identification. Statistical performance of the algorithm is described and evaluated for the human data. Potential meanings of the different parameter values and the performance results are described.

Track A. Communications Systems

Session: TAa2 – Network Coding

Chair: ***Athina Markopoulou,*** *University of California, Irvine*

TA2a-1 **8:15 AM**

Network Alignment

Syed Jafar, University of California, Irvine

Recent progress on applications of interference alignment principles to network coding problems, in particular distributed storage and index coding, is reviewed.

TA2a-2 **8:40 AM**

Network Coding for Data Replication over Wireless Networks

Lorenzo Keller, Christina Fragouli, École Polytechnique Fédérale de Lausanne (EPFL)

In this paper we study the use network coding techniques for improving the performance of data replication over wireless networks. We focus on the problem where a read-only database has to be replicated to a set of mobile wireless nodes using low bit-rate broadcast wireless links. We investigate protocols that allow to achieve different trade-offs between desired performance metrics, such as delay and reliability.

TA2a-3 **9:05 AM**

A Fundamental Approach to Securing Data in the Cloud from Adversarial Attacks

Salim El Rouayheb, Sameer Pawar, Kannan Ramchandran, University of California, Berkeley

Cloud storage systems are now a growing paradigm for providing reliable and inexpensive "on-demand" data storage services. This is achieved by storing the data redundantly on a large number of unreliable nodes formed of commodity hardware. A major concern is how to guarantee the data security against malicious intruders. From a theoretical perspective, cloud systems pose a new challenge due to their dynamic behavior resulting from nodes frequently failing and being repaired. Thus, a single malicious node may corrupt all the data stored in the system. Assuming a computationally unbounded adversary that controls a fraction of the nodes, we give upper bounds on the maximum amount of information that can be stored safely in the cloud and provide explicit code constructions for important cases.

TA2a-4 **9:30 AM**

Network Coding for Security and Privacy

Tracey Ho, California Institute of Technology

Network coding can be used for providing security and privacy against adversaries that corrupt or observe a limited but unknown subset of network links. In this talk we provide an overview of our recent results on this topic.

Track A. Communications Systems

Session: TAb2 – Relaying through Frequency Selective Channels

Chair: ***Andy Klein,*** *Worcester Polytechnic Institute*

TA2b-1 **10:15 AM**

Distributed Single Carrier Frequency-Domain Equalization for Multi-Relay Cooperative Networks over Frequency Selective Rician Channels

Homa Eghbali, Sami Muhaidat, Simon Fraser University; Ibrahim Abualhaol, Khalifa University of Science, Technology and Research

In this paper, we investigate the performance of single-carrier frequency-domain equalization (SC-FDE) for distributed space-time block coded (DSTBC) systems with the Amplify-and-forward (AF) protocol. We model all links, i.e., source-destination, source-relay, and relay-destination, as frequency selective Rician fading channels. To overcome the loss in spectral efficiency, associated with the deployment of orthogonal DSTBCs, we present several relay selection strategies tailored for frequency selective channels. In particular, we present and study the so-called norm-based relay selection algorithm (NBRS), instantaneous mutual information-based relay selection (CBRS), singular value based relay selection (SVRS), and equalizer output signal quality-based relay selection (EQRS) strategies.

TA2b-2 **10:40 AM**

Cooperative BICM-OFDM Systems for Frequency-Selective Relay Channels

Reza Heidarpour, Murat Uysal, University of Waterloo

Abstract here.

TA2b-3 **11:05 AM**

On Relay Selection in Frequency Selective Channels

Qingxiong Deng, Andrew Klein, Worcester Polytechnic Institute

In this paper, we consider the problem of relay selection in cooperative relay networks with frequency selective fading. Recent results for relays in flat fading channels demonstrate a performance and implementation advantage in using relay selection as opposed to more complicated distributed space-time coding schemes. Motivated by these results, we explore the use of relay selection for the case when all channels have intersymbol interference. In particular, we focus on the performance of relaying strategies when multiple decode-and-forward relays share a single channel orthogonal to the source. We proposed two relay selection methods and compared their performance when a joint MMSE-DFE equalizer at the destination is used.

TA2b-4 **11:30 AM**

Superposition Coding for Cooperative BICM-OFDM Systems

Toufiqul Islam, Robert Schober, University of British Columbia; Ranjan K Mallik, Indian Institute of Technology, Delhi; Vijay K Bhargava, University of British Columbia

Network coding over wireless networks can provide considerable throughput gains without sacrificing the achievable diversity gain. In this paper, we propose a novel symbol level superposition coding scheme for multisource cooperative communication employing bit-interleaved coded modulation (BICM) and orthogonal frequency division multiplexing (OFDM). We consider an amplify-and-forward (AF) relaying strategy, where the relay forwards a linear combination of the symbols received from the different sources to the destination. In contrast to existing symbol level network coding protocols, transmissions from different sources do not have to be received simultaneously at the relay. We derive a closed-form upper bound on the worst-case pair-wise error probability and the diversity order of the considered system. Simulation results confirm the diversity order analysis and show considerable performance gains compared to bit-level network coding protocols.

Track D. Signal Processing and Adaptive Systems

Session: TAa3 – Advances in Compressive Sensing

Chair: ***Christoph Studer,*** *Rice University*

TA3a-1 **8:15 AM**

An Empirical-Bayes Approach to Compressive Sensing via Approximate Message Passing

Jeremy Vila, Philip Schniter, Ohio State University

The approximate message passing (AMP) algorithm recently proposed by Donoho, Maleki, and Montanari yields a computationally attractive solution to the l1-norm optimization problem that lies at the heart of compressed sensing, and shows strong connections to minimax-optimal estimation. Meanwhile, AMP has been generalized for Bayesian compressive sensing under a known, but otherwise generic, signal prior. The former AMP is appropriate when nothing is known apriori about the signal distribution, whereas the latter is appropriate when the signal prior is perfectly known. In this paper, we attempt to navigate the space between these extremes by modeling the signal as generated from a Gaussian mixture prior with unknown deterministic parameters. We then jointly estimate the signal, and learn the prior parameters, using the expectation maximization (EM) algorithm, which calls Gaussian-mixture-AMP as a subroutine. Numerical experiments confirm the excellent performance of the proposed approach, which in some cases yields an average performance that exceeds fully that of informed AMP, due to the possibility of realization-specific data fitting.

TA3a-2 **8:40 AM**

Compressive Sensing under Multiplicative Uncertainties: An Approximate Message Passing Approach

Jason Parker, Air Force Research Laboratory; Volkan Cevher, École Polytechnique Fédérale de Lausanne (EPFL); Philip Schniter, Ohio State University

In this work, we consider compressive sensing (CS) when there is uncertainty in the linear matrix transformation as well as in the observations of the transformation outputs. Such work is motivated by the practical case that there exist imperfections in the signal acquisition hardware. While previous work has focused on analyzing the worst-case effect of additive matrix perturbations

on classical CS algorithms, we propose a new algorithm whose goal is mean-squared-error-optimal inference in the presence of these uncertainties. In particular, we extend the Approximate Message Passing (AMP) approach originally proposed by Donoho, Maleki, and Montanari, and recently generalized by Rangan, to the case of (sta- tistically decoupled) probabilistic uncertainties in the elements of the measurement matrix. Furthermore, we propose a "turbo-AMP" approach that allows us to handle certain forms of statistical coupling among the multiplicative uncertainties.

TA3a-3 9:05 AM

Compressive Sensing: to Compress or not to Compress

Davis Kirachaiwanich, Qilian Liang, The University of Texas at Arlington

In this paper, we consider the compressive sensing scheme from the information theory point of view and derive the lower bound of the probability of error for CS when length N of the information vector is large. The result has been shown that, for an i.i.d. Gaussian distributed signal vector with unit variance, if the measurement matrix is chosen such that the ratio of the minimum and maximum eigenvalues of the covariance matrices is greater or equal to [4/(MK+1)], then the probability of error is lower bounded by a non-positive value; which implies that the information can be perfectly recovered from the CS scheme. On the other hand, if the measurement matrix is chosen such that the minimum and maximum eigenvalues of the covariance matrices are equal, then the error is certain and the perfect recovery can never be achieved.

TA3a-4 9:30 AM

Spread Representations

Jean Jacques Fuchs, Université de Rennes 1

Sparse representations, where one seeks to represent a vector on a redundant basis using the smallest number of basis vectors, appears to have numerous applications. The other extreme, where one seeks a representation that uses all the basis vectors, might be of interest if one manages to spread the information nearly equally over all of them. Minimizing the l-infinity-norm of the vector of weights is one way the find such a representation. Properties of this solution and dedicated fast algorithms allowing to find it are developed. Applications are to be found in robust data coding and improving achievable data rates over amplitude constrained channels.

Track D. Signal Processing and Adaptive Systems

Session: TAb3 – Sparse Reconstruction

Chair: ***Geert Leus,*** *Technical University of Delft*

TA3b-1 10:15 AM

New Bounds for Restricted Isometry Constants in Orthogonal Multi Matching Pursuit

Jian Wang, Byonghyo Shim, Korea University

As a greedy algorithm recovering sparse signal from compressed measurements, Orthogonal Matching Pursuit (OMP) and Orthogonal Multi Matching Pursuit (OMMP) algorithm have received much attention in recent years. In this paper, we present a condition ensuring the perfect recovery of K sparse signal in the OMMP and OMP algorithm. To be specific, we show that perfect reconstruction of K sparse signals is guaranteed for the OMMP algorithm if the sensing matrix satisfies the restricted isometric property (RIP) of order SK with isometric constant $$\delta_{SK} < \frac{\sqrt{S}}{\sqrt{K}+ 2 \sqrt{S}}$$. We also show that the OMP algorithm can recover K sparse signals perfectly if the isometric constant of the sensing matrix satisfies $${\delta _{K + 1}} < \frac{1} {{\sqrt K + 1}}$$.

TA3b-2 10:40 AM

Cyclic Greedy Algorithms for Recovering Compressively Sampled Sparse Signals

Bob Sturm, Mads Christensen, Aalborg University; Rémi Gribonval, INRIA

We empirically show how cyclically applying the pure greedy algorithm (i.e., Matching Pursuit) can recover compressively sampled sparse signals from a variety of sparse vector distributions as well as the orthogonal greedy algorithm (i.e., Orthogonal Matching Pursuit). This implies that we can have the same performance of Orthogonal Matching Pursuit but with a much more simple routine. We also look at a cyclic application of the step-wise projection algorithm (i.e., orthogonal least-squares), which is known to improve further the performance of the pure greedy algorithm. The final paper will include more comparisons with other recovery algorithms, and an analysis of the cyclic pure greedy algorithm within the context of compressed sensing.

TA3b-3 **11:05 AM**

Greedy Sparsity-Constrained Optimization

Sohail Bahmani, Carnegie Mellon University; Petros Boufounos, Mitsubishi Electric Research Labs; Bhiksha Raj, Carnegie Mellon University

Finding optimal sparse solutions to "estimation" problems, particularly for underdetermined systems of linear equations has recently gained much attention. Most existing literature assumes that the discrepancy to be minimized between the optimal solution and the estimate is measured by quadratic functions. However, in many applications discrepancy is measured in more general forms such as log-likelihood. In many such applications, regularization by L1-norm has been shown to provide sparse solutions, but their optimality is not well understood. In this paper we present an algorithm for sparsity-constrained optimization, provided the cost function satisfies a "Stable Hessian Property", with quantifiable guarantees.

TA3b-4 **11:30 AM**

Power-Iterative Strategy for lp-l2 Optimization for Compressive Sensing: Towards Global Solution

Jie Yan, Wu-Sheng Lu, University of Victoria

We study nonconvex relaxation of the combinatorial l0-minimization for compressive sensing. In an lp-l2 minimization setting with $p < 1$, we propose an iterative algorithm with two distinct features: (i) use of a proximal-point (P-P) objective function composed of a convex quadratic term and an lp-norm term, and a fast solver for global minimization of the P-P function in each iteration; and (ii) a power-iterative strategy that begins by solving a convex l1-l2 problem whose solution is then used to start next lp-l2 problem with p close to but less than one. The process continues with gradually reduced p until a target power pt is reached. Using simulations the algorithm is shown to offer considerable performance gain.

Track C. Networks

Session: TAa4 – Next Generation Network Science

Co-Chairs: ***Victor Preciado,*** *University of Pennsylvania* ***and Ali Jadbabaie,*** *University of Pennsylvania*

TA4a-1 **8:15 AM**

Network Synthesis for Dynamical System Stabilization

Miroslav Pajic, University of Pennsylvania; Shreyas Sundaram, University of Waterloo; George J. Pappas, Rahul Mangharam, University of Pennsylvania

We study the problem of stabilizing a linear system over a wireless control network. We propose a scheme where each wireless node maintains a scalar state, and periodically updates it as a linear combination of neighboring plant outputs and node states. We make connections to decentralized fixed modes and structured system theory to provide conditions on the network topology that allow the system to be stabilized. Our analysis provides the minimal number of feedback edges that have to be introduced to stabilize the system over a network, and shows that as long as the network connectivity is larger than the geometric multiplicity of any unstable eigenvalue, stabilizing controllers can be constructed at each actuator. A byproduct of our analysis is that by co-designing the network dynamics with the controllers, delays in the network are not a factor in stabilizing the system.

TA4a-2 **8:40 AM**

A Contrasting Look at Network Formation Models and Their Application to the Minimum Spanning Tree

David Alderson, Gerald Brown, Naval Postgraduate School; D.B. McPherson, U.S. Navy

Networks are prevalent in man-made and natural systems throughout the world. Despite recent efforts to characterize and catalog networks of all kinds, there is considerably less known about the forces that drive network formation. For many complex systems it is unclear whether networks are the result of an explicit effort to achieve some overarching global system objective, or if network structure is just a byproduct of local, selfish decisions. In this talk, we review network formation models and conduct numerical experiments to contrast their behavior and the structural features of the networks they generate. We focus primarily on problems related to the formation of minimum spanning trees and consider the cost of selfish behavior, more commonly known as the price of anarchy, in network formation. We also explore differences between local, decentralized methods for network formation and their global, centralized counterparts.

TA4a-3 **9:05 AM**

The Role of Local Structural Information in Viral Information Spreading

Victor Preciado, Ali Jadbabaie, University of Pennsylvania

The intricate structure of many large-scale networked systems has attracted the attention of the scientific community, leading to many results attempting to explain the relationship between a network structural features and the performance of processes taking place in the network. A common approach to study the relationship between structure and performance is to use synthetic network models in which structural properties of interest, such as degree distributions, are prescribed. Although very common, this approach presents a major flaw: Synthetic network models implicitly induce many structural properties that are not directly controlled and can be relevant to the network performance. In this paper, we propose an alternative approach to overcome this flaw. Our approach is not based on synthetic models; instead, we use algebraic graph theory and convex optimization to study how structural properties constrain performance metrics of the network. We formulate this novel approach by analyzing the role of network structural properties in epidemic-style processes of information dissemination in networked systems. We illustrate our approach with nontrivial numerical simulations on an online social network.

TA4a-4 **9:30 AM**

Learning, Memory and the Role of Neural Network Architecture

Ann Hermundstad, Kevin Brown, Danielle Bassett, Jean Carlson, University of California, Santa Barbara

The performance of information processing systems, from artificial neural networks to natural neuronal ensembles, depends heavily on the underlying system architecture. In this study, we compare the performance of parallel and layered network architectures during sequential tasks that require both acquisition and retention of information, thereby identifying tradeoffs between learning and memory processes. During the task of supervised, sequential function approximation, networks produce and adapt representations of external information. Performance is evaluated by statistically analyzing the error in these representations while varying the initial network state, the structure of the external information, and the time given to learn the information. We link performance to complexity in network architecture by characterizing local error landscape curvature. We find that variations in error landscape structure give rise to tradeoffs in performance; these include the ability of the network to maximize accuracy versus minimize inaccuracy and produce specific versus generalizable representations of information. Parallel networks generate smooth error landscapes with deep, narrow minima, enabling them to find highly specific representations given sufficient time. While accurate, however, these representations are difficult to generalize. In contrast, layered networks generate rough error landscapes with a variety of local minima, allowing them to quickly find coarse representations. Although less accurate, these representations are easily adaptable. The presence of measurable performance tradeoffs in both layered and parallel networks has implications for understanding the behavior of a wide variety of natural and artificial learning systems.

Track C. Networks

Session: TAb4 – Bio-inspired Models and Algorithms for Information Processing in Complex Networks

Chair: ***Usman Khan,*** *Tufts University*

TA4b-1 **10:15 AM**

On Scheduling Without a Master Clock: Coupled Oscillator Time Division Multiplexing

Andrea Rueetschi, Anna Scaglione, University of California, Davis

Most scheduled communication system rely on either central coordination, or on the presence of an external reference clock that is accessible to all nodes in the network. Such requirements often limit the scalability and applicability of time division multiple access (TDMA) solutions to ad-hoc networks, which largely rely on conflict resolution based on random access mechanism. We show that, by borrowing mechanisms of coordination found in nature, we can self-organize nodes in a network in time division without a central clock, nor a common reference signal. We also show that a common clock reference and a conflict free schedule can emerge from our signaling control scheme, using simple local computations that are based on the so called Pulse Coupled Oscillator (PCO) dynamics. Compared to the prior art on PCO, our work provides an integrated solution for network synchronization and collision free TDMA that is completely decentralized and can lead to efficient transmission of data at a regular and reliable pace. We discuss how this scheme can be used to provide an alternative to the popular Zigbee interface, and produce collision free clustered synchronous networks.

TA4b-2 **10:40 AM**

On the Effects of Topology and Node Distribution on Learning over Complex Adaptive Networks

Sheng-Yuan Tu, Ali H. Sayed, University of California, Los Angeles

Collective motion in biological systems emerges from local interactions among individual agents. Adaptive networks, consisting of a collection of nodes with learning and local information processing abilities, have been used to model and regenerate collective behavior, such as fish swimming in schools, birds flying in V-formations, or bees swarming towards a hive. The motion behavior is usually impacted and induced by a small fraction of the agents that are most informed about the network goal. In this paper, we investigate the effects of network topology, node distribution, and heterogeneous sources of information on the overall learning ability by the network.

TA4b-3 **11:05 AM**

Discrete-Time Opinion Dynamics

Seyed Rasoul Etesami, Angelia Nedic, University of Illinois, Urbana-Champaign

We discuss Hegselmann-Krause model for opinion dynamics in discrete-time for a symmetric confidence bound. We are interested in developing bounds on convergence time, and in the characterization of the limiting behavior in terms of the initial profile, the confidence bound and the number of agents. In particular, we estimate the number of limiting points and address the distance among these points.

TA4b-4 **11:30 AM**

Gossiping Information Dissemination Through Distributed Femtocell Caching

Alexandros G. Dimakis, University of Southern California

We discuss the benefits of distributed caching in information dissemination for wireless mobile clients. The focus is on simple randomized gossip algorithms combined with optimized caching to disseminate content so as to reduce the macro-cell load and enable frequency re-use.

Track H. Speech, Image and Video Processing

Session: TAa5 – Image and Video Retrieval

Chair: ***Ramakrishna Vedantham,*** *Nokia Research*

TA5a-1 **8:15 AM**

Mobile Visual Search Using Image and Text Features

Sam Tsai, Huizhong Chen, David Chen, Stanford University; Ramakrishna Vedantham, Radek Grzeszczuk, Nokia; Bernd Girod, Stanford University

We present a mobile visual search system that incorporates both image and text features. On the mobile device, a joint interest point and text detection algorithm finds features in a query image. Image features are encoded using compact descriptors. Localized text patches are rectified and recognized using an OCR engine. Image and text features are transmitted to a server and searched through a database. Finally, a joint text and image feature comparison method is used to geometrically verify the retrieved results.

TA5a-2 **8:40 AM**

A Compact Index for Large-Scale Mobile Visual Search

David Chen, Sam Tsai, Vijay Chandrasekhar, Gabriel Takacs, Huizhong Chen, Stanford University; Ramakrishna Vedantham, Radek Grzeszczuk, Nokia Research Center; Bernd Girod, Stanford University

We present a new compact index, called the Residual Enhanced Visual Vector (REVV), which uses significantly less memory than the popular vocabulary tree framework while attaining comparable retrieval accuracy. Unlike other recent methods based on visual word residuals, REVV is optimized for interactive mobile visual search settings where achieving low query latency is critical. The small memory footprint of REVV enables a large visual database to be stored and searched directly on a mobile device that has limited memory, thus enabling on-device image matching where no data is uploaded to a remote server.

TA5a-3 **9:05 AM**

Multiple-Channel Compact Visual Descriptor with Adaptive Channel Learning

Rongrong Ji, Harbin Institute of Technology; Ling-Yu Duan, Jie Chen, Peking University; Hongxun Yao, Harbin Institute of Technology; Tiejun Huang, Wen Gao, Peking University

In this paper, we propose a multiple-channel coding scheme for the purpose of compact visual descriptor in the scenario of mobile visual search. Different from previous work in near-duplicated visual retrieval which sends the entire query image, we make use of the explosive growth of the computational power at the mobile device to directly extract compact visual descriptors in the cell phone. Comparing with the state-of-the-arts works in compact visual descriptors, we make use of the contextual information to learning a set of coding channels for compressing the original Bag-of-Words visual signature with respect to different visual or contextual division scheme. The channel division is learnable, based on either visual statistics or the side information, such as GPS tags for mobile visual search. We have deployed the proposed scheme within a 10 million scale mobile landmark search system, with application to both Apple and Android cell phones. Extensive comparisons to state-of-the-art works have demonstrated our effectiveness for real-world mobile visual query requirements.

TA5a-4 **9:30 AM**

Efficient Re-Ranking in Vocabulary Tree-Based Image Retrieval

Xiaoyu Wang, University of Missouri; Ming Yang, Kai Yu, NEC Laboratories America, Inc.

Image retrieval using a large vocabulary tree of local invariant features can efficiently handle databases with millions of images. However, a costly re-ranking step is generally required to re-order the top candidate images to enforce spatial consistency among local features. In this paper, we propose an efficient re-ranking approach which takes advantage of the vocabulary tree quantization to conduct fast feature matching. The proposed re-ranking algorithm involves no operations in the high-dimensional feature space and does not assume a global transform between a pair of images, thus, it not only dramatically reduces the computational complexity but also improves the retrieval precision, which is validated using 1.26 million images in the public ImageNet dataset and the San Francisco Landmark dataset including 1.7 million images.

Track H. Speech, Image and Video Processing

Session: TAb5 – Sparse Representations with Applications to Images and Video

Chair: ***Trac Tran Tran,*** *Johns Hopkins University*

TA5b-1 **10:15 AM**

Robust Multi-Dimensional Scaling via Outlier Sparsity Control

Pedro Forero, Georgios B. Giannakis, University of Minnesota

Multidimensional scaling (MDS) is a tool with well-documented merits in diverse applications dealing with exploratory data analysis based on dissimilarity (distance) data. Its goal is to find an embedding of N objects in a $p<N$ dimensional space such that inter-vector distances approximate the given dissimilarities. If outliers are present in the dissimilarity data, classical MDS approaches yield grossly erroneous embeddings. This paper introduces a robust approach to MDS by controlling the sparsity present in the vector of outliers. The novel approach relies on a majorization-minimization scheme and leverages tools from sparsity-aware signal processing. The resultant outlier-resilient MDS algorithms can identify the outliers at reduced computational complexity relative to classical MDS alternatives. Moreover, they can identify structured outliers in situations where, e.g., a group of dissimilarities with respect to a fixed object are all contaminated by outliers. Numerical simulations on synthetic and real data sets illustrate the merits of the proposed algorithms.

TA5b-2 **10:40 AM**

Architectures for Compressive Sampling of Correlated Signals

Ali Ahmed, Justin Romberg, Georgia Institute of Technology

We will discuss several ways in which recent results on the recovery of low-rank matrices from partial observations can be applied to the problem of sampling ensembles of correlated signals. We will present several architectures that use simple analog building blocks (vector-matrix multiply, modulators, filters, and ADCs) to implement different types of measurement schemes with “structured randomness”. These sampling schemes allow us to take advantage of the (a priori unknown) correlation structure of the ensemble by reducing the total number of observations required to reconstruct the collection of signals. We will discuss scenarios that use an ADC for every channel, and those which multiplex the channels onto a single line which is sampled with a single ADC.

TA5b-3 **11:05 AM**

Compressed-Sensing Recovery of Images and Video Using Multi-Hypothesis Predictions

Chen Chen, Eric Tramel, James Fowler, Mississippi State University

Compressed-sensing recovery of images and video sequences driven by multihypothesis predictions is considered. Specifically, for still images, multiple predictions drawn for an image block are made from spatially surrounding blocks. For video, multihypothesis predictions of the current frame are generated from one or more reference frames. In each case, the predictions are used to generate a residual in the domain of the compressed-sensing random projections. This residual being typically more compressible than the original signal leads to improved reconstruction quality. To appropriately weight the hypothesis predictions, a Tikhonov regularization to an ill-posed least-squares optimization is proposed. This method is shown to outperform alternative recover strategies not employing multihypothesis prediction.

TA5b-4 **11:30 AM**

Sparsity-Based Human Activity Recognition for Mobile Computing Devices

Victor Shia, Allen Yang, Ruzena Bajcsy, University of California, Berkeley

We propose a sparsity-based classification method suitable for mobile computing devices and body sensor networks. In real-time, our system segments and classifies human actions using a system of multiple Intel SHIMMER wireless sensors communicating via Bluetooth to a smart phone. The classifier uses a training set of prior human actions and the Homotopy l1-minimization to determine the membership of a test action. The accuracy of the system is validated using a public wearable action recognition database comprised of accelerometry data of over 20 subjects performing 7 actions.

TA5b-5 **11:55 AM**

Sparsity-Based Face Recognition Using Discriminative Graphical Models

Umamahesh Srinivas, Vishal Monga, Pennsylvania State University; Yi Chen, Trac D. Tran, The Johns Hopkins University

We propose a graphical learning framework for robust automatic face recognition, utilizing sparse signal representations from face images as features for classification. Our approach combines two key ideas from recent work in the areas of locally adaptive sparsity for face recognition, and discriminative learning of graphical models. In particular, we learn discriminative graphs on sparse representations obtained from distinct local slices of a face. The graphical models are learnt in a manner such that conditional correlations between these sparse features are first discovered (in the training phase), and subsequently exploited to bring about significant improvements in recognition rates. Because existing sparsity-based face recognition techniques use class (face) specific reconstruction error as a recognition statistic, experimental results show that its complementary merits against the proposed approach can further be mined into building a powerful meta-classifier for face recognition.

Track E. Array Signal Processing

Session: TAa6 – Waveform Design and MIMO Radar

Chair: ***Visa Koivunen,*** *Aalto University*

TA6a-1 **8:15 AM**

Cluster Allocation Schemes for Target Tracking in Multiple Radar Architectures

Hana Godrich, Princeton University; Athina Petropulu, Rutgers University; H. Vincent Poor, Princeton University

There is growing interest in multiple, widely separated, radar systems that employ mobile stations such as ground surveillance radars (GSRs). These are usually portable light-weight systems that may be carried by one person or mounted on a vehicle and may be employed in large numbers. In a resource-aware operation, only a subset of the existing transmit and receive antennas may be used to accomplish a given target localization accuracy. Commonly, multiple target localization is performed by scanning a given area cell-by-cell. In this paper, clustering of the multiple radar system is proposed, such that each cluster/subset covers a different search cell with the same accuracy threshold. For a specified number of search cells and accuracy threshold, the overall number of active radars is minimized. Fast approximation algorithms are proposed and evaluated with respect to exhaustive search.

TA6a-2 **8:40 AM**

Synergistic MIMO SAR and GMTI

Duc Vu, Luzhou Xu, Jian Li, University of Florida

Multi-input multi-output (MIMO) radar is beginning to attract a significant amount of attention from researchers and practitioners alike due to its potential of advancing the state-of-the-art of modern radar. We focus herein on a MIMO radar scheme in which both the transmitting and receiving antennas are collocated (closely spaced) for coherent transmission and detection. This type

of MIMO radar is referred to as mono-static MIMO radar. Unlike a standard phased-array radar, which transmits scaled versions of a single waveform, a mono-static MIMO radar system can transmit via its antennas multiple probing signals that may be quite different from each other. This waveform diversity offered by MIMO radar enables superior capabilities compared with a standard phased-array radar. When the transmit antennas transmit orthogonal waveforms, the virtual array of the radar system is a filled array with an aperture up to M times that of the receive array, where M is the number of transmit antennas. In this paper, we focus our attention on synergistic MIMO synthetic aperture radar (SAR) and ground moving target indication (GMTI) so that the tasks of the SAR imaging of stationary targets and background and SAR based GMTI can be performed simultaneously by developing state-of-the-art MIMO SAR systems that take advantage of this significantly increased virtual aperture size.

TA6a-3 **9:05 AM**

Resource Allocation in Widely Distributed MIMO Radars in Non-Ideal Conditions

Tuomas Aittomaki, Aalto University; Hana Godrich, Rutgers University; Visa Koivunen, Aalto University; H. Vincent Poor, Princeton University

Widely distributed multiple-input multiple-output (MIMO) radars using transmitters and receivers distributed over a large area can offer improved target detection, estimation, and tracking capabilities. In order to prolong the operation of such a distributed radar system, it is important to save power whenever possible while keeping the performance within the predetermined bounds. This can be achieved by optimizing the transmit power of the transmitters in the system with the given performance constraint. For example, the transmit power is minimized with constraints on the probability of detection and false alarm. MIMO radar resource allocation has been considered before in ideal conditions, such as independent scattering and white noise. In this paper, we provide solution to the power allocation of the widely distributed MIMO radar in non-ideal conditions, including correlated scattering and colored noise.

TA6a-4 **9:30 AM**

Centralized and Distributed Tests for Moving Target Detection with MIMO Radars in Clutter of Non-Homogeneous Power

Pu Wang, Hongbin Li, Stevens Institute of Technology; Braham Himed, Air Force Research Laboratory

Clutter observed in distributed multiple-input multiple-output (MIMO) radars is often nonhomogenous, due to multi-static configuration and azimuth-selective backscattering in such systems. We consider herein moving target detection using a MIMO radar on a stationary platform so that the clutter is bandlimited and can be represented by a common subspace structure, which however has distinct subspace coefficients for different transmit-receive pairs and/or across different resolution cells to model nonhomogeneous power variations. We develop both a centralized and, respectively, a distributed implmentation of a generlized likelihood ratio test (GLRT) to explore the resource (power/bandwith/complexity) consumption versus performance tradeoff. The centralized GLRT requires the distributed receivers to forward the outputs of all matched filters (one for each waveform) to a fusion center, where a global test statistic is computed. Meanwhile, the distributed GLRT performs local data aggregation by computing a single local test statistic at each receiver, which is then sent to a fushion center for noncoherent combininng. We present extensive numerical results to demonstrate the performance of the proposed GLRTs and other relevant detectors.

Track E. Array Signal Processing

Session: TAb6 – Network Beamforming and Relaying via Multiple Antennas

Chair: ***Sergiy Vorobyov,*** *University of Alberta*

TA6b-1 **10:15 AM**

Collaborative Beamforming in Wireless Sensor Networks

Serkan Sayilir, Yung-Hsiang Lu, Dimitrios Peroulis, Y. Charlie Hu, Byunghoo Jung, Purdue University

Collaborative beamforming (CB) is an energy efficient transmission scheme in wireless sensor networks (WSNs). Despite the promising aspects of CB, its practical implementation remains largely unexplored and the challenges, namely frequency, phase, and data synchronization, must be addressed for successful deployment. We propose a CB protocol with compatible transceiver architecture. The protocol uses a phase-locked loop (PLL) continuously operating in closed-loop for frequency synchronization, a local two-way phase estimation and remote one-way calibration technique for phase synchronization, and a data entrainment technique to achieve data synchronization with minimal data traffic. The efficiency analysis including carrier jitter demonstrates the feasibility of the proposed CB protocol with reasonably high gains.

TA6b-2 **10:40 AM**

Joint Power Control and Relay Design in Underlay Cognitive Networks with Multiple Transmitter-Receiver Pairs

Keyvan Zarifi, Sofiene Affes, INRS-EMT; Ali Ghrayeb, Concordia University

We consider an underlay cognitive network with L transmitter-receiver pairs and K relays in a two-hop half-duplex cooperative scheme. While the transmitters use a shared channel to transmit to the relays, the relays use either a shared channel or L orthogonal channels to communicate with the L receivers. For both second hop channel cases, we jointly determine the transmitters' powers and the relaying weights that maximize the worst signal-to-interference-plus-noise ratio subject to the transmitters' total and individual and the relays' total power constraints while guaranteeing that the interference powers on M existing primary users are below some required thresholds.

TA6b-3 **11:05 AM**

Beamforming in MIMO Broadcast Relay Networks with Multiple Antenna Users

Godfrey Okeke, Yindi Jing, Witold Krzymien, University of Alberta

This paper studies a multiple-input multiple-output (MIMO) broadcast relay channel (BRC) in which a multiple-antenna base station (BS) communicates with multiple-antenna users through a fixed infrastructure-based multiple-antenna relay station (RS). Applying dirty paper coding (DPC) at the BS and linear processing at the RS, our goal is to find the optimal input covariance matrices at the BS and the beamforming matrix at the RS that maximize the system sum-rate. To solve the optimization problem, a more tractable dual multiple access relay channel (MARC) is investigated and an iterative algorithm is proposed to obtain the optimal matrices for the dual system. The mapping from the resulting covariance matrices for the MARC to the covariance matrices for the original BRC is derived. Unlike other existing MIMO BRC schemes, designed for networks with single-antenna users only, our solution is applicable to networks with multiple-antenna users. Compared with two such single-antenna-user schemes, simulations show that the proposed scheme outperforms the All-Pass Relay design and performs similar to the SVD-Relay design. Also, the proposed design performs close to a sum-rate upper bound with the gap decreasing with increasing number of users' antennas.

TA6b-4 **11:30 AM**

A Relay Selection Approach to Bi-Directional Collaborative Communications with Imperfect CSI

Fadhel Al-Humaidi, Shahram ShahbazPanahi, University of Ontario Institute of Technology

We herein study a network beamformer for a two-way relay network, consisting of two transceivers and multiple relay nodes, in the presence of uncertainty in the knowledge of channel coefficients. More specifically, one of the transceivers (i.e., master transceiver) knows the (near) channel coefficients between itself and the relays while it is assumed to have only statistical information about the (far) channels between the other transceiver and the relay nodes. A well-known approach to design a two-way network beamformer is the minimization of the total transmit power, consumed in the whole network, subject to two constraints on the transceivers' received signal-to-noise ratios (SNRs), which guarantee the quality of service at both transceivers. Not however that in the presence of uncertainty in the master transceiver's knowledge of the far channels, the transceivers' received SNRs as well as the total transmit power are random quantities and their true values are not available at this transceiver. As such, we aim to minimize the total transmit power, as perceived by the master transceiver, subject to two probabilistic constraints on random SNRs. These constraints ensure that the outage probabilities of the transceivers' received SNRs are less than given thresholds. We prove rigourously that this approach leads to a relay selection scheme where the master transceiver should select the relay with the best near channel link.

Track G. Architecture and Implementation

Session: TA7 – Architectures for Wireless Communications

Chair: ***Joe Cavallero,*** *Rice University*

TA7-1 **8:15 AM**

An Efficient Architecture for Iterative Soft Reliability-Based Majority-Logic Non-Binary LDPC Decoding

Xinmiao Zhang, Fang Cai, Case Western Reserve University

Non-binary low-density parity-check (NB-LDPC) codes have better error-correcting performance than their binary counterparts at the cost of higher decoding complexity when the code length is moderate. Compared to other NB-LDPC decoding algorithms, the iterative reliability-based majority-logic decoding can achieve better performance-complexity tradeoff. In this paper, an efficient partial-parallel shift-message decoder architecture is proposed for cyclic NB-LDPC codes based on the iterative soft

reliability-based majority-logic decoding (ISRB-MLGD). Although the accumulated soft reliabilities in the ISRB algorithm require longer word length, and accordingly longer critical path, the decoder architecture and control logic can be simplified. Particularly, the message shifting is implemented by memories concatenated with variable node units to reduce the area. Moreover, the scheduling of the computations in the check node units is optimized to eliminate the message routing network. Compared to the iterative hard reliability-based decoder for a (255, 175) NB-LDPC code over GF(256), the proposed ISRB decoder can achieve around 0.8dB coding gain with less than three times the complexity.

TA7-2 **8:40 AM**

Architecture Exploration, Development and Teaching Platform for Orthogonal Frequency Division Multiplexing (OFDM) Systems

Antonio Mondragon-Torres, Mahesh Kommi, Tamoghna Bhattacharya, Rochester Institute of Technology

The objective is to have a complete system level Orthogonal Frequency Division Multiplexing (OFDM) development platform where students can use it to explore and identify the different processing blocks available on a modern communications system. The platform will allow monitoring the inputs and outputs of every block to observe the signals as well as to substitute the block by their own implementation. This could be done using a high level language such as Matlab/Simulink and C/C++, or the block can be substituted by hardware generation components such as: Simulink to Hardware Description Language (HDL), C to HDL and directly by a HDL implementation. Also the concept of Hardware In the Loop (HIL) is introduced where the block is actually run on Field Programmable Gate Array (FPGA) hardware. The platform allows the use of the FPGA as a hardware accelerator or coprocessor. Different tradeoffs in algorithm hardware implementations can be explored such as: signal throughput, floating to fixed point conversion, hardware resources used for FPGA, silicon area estimates for ASIC, power consumption, maximum operating frequency, signal to quantization noise ratio (SQNR), to mention some.

TA7-3 **9:05 AM**

Improved Iterative Soft-Reliability-Based Majority-Logic Decoding Algorithm for Non-Binary Low-Density Parity-Check Codes

Chenrong Xiong, Zhiyuan Yan, Lehigh University

Non-binary low-density parity-check (LDPC) codes provide better error performance than their binary counterparts, but unfortunately their decoding complexity is a significant challenge. For this reason, the iterative soft-reliability-based (ISRB) majority-logic decoding algorithm is attractive for non-binary LDPC codes due to its reduced complexity. In this paper, we propose an improved ISRB majority-logic decoding algorithm by using a new reliability update. This improved algorithm avoids the accumulation of the error message of the ISRB majority-logic decoding algorithm, and hence improves error performance and achieves faster convergence while maintaining the latter's low complexity. Simulation results show that the proposed algorithm achieves 0.15 dB coding gain over the ISRB majority-logic decoding algorithm for a (255,175) cyclic Euclidean geometry LDPC code over GF(2^8). Furthermore, hardware implementations of the proposed algorithm demonstrate its advantage in complexity.

TA7-4 **9:30 AM**

LTE Layer 1 Software Design on Multi-Core DSP Architectures

Arokia Irudayaraj, Michael Brogioli, Nitin Jain, Umang Garg, Freescale Semiconductor, Inc.

The evolving next generation international standards in wireless communications such as LTE (Long Term Evolution) are a leap forward to simultaneously satiate the quest for improved spectrum utilization and support an ever increasing demand for data traffic. Software development for the LTE standard manifests in an increased algorithmic and computational complexity which necessitates adoption of advanced, next generation, high performance DSP processors. By exploiting advancements in multicore DSP architectures, special purpose baseband on-chip hardware acceleration, and mature software tool chains, efficient software development for wireless technologies such as LTE Layer1 can be achieved. This paper elucidates a series of techniques and examples that leverage said multicore DSP architectures for LTE Layer 1 with respect to mapping software components on hardware accelerators, scalable load balancing across cores, component optimization, cache usage optimization and overall system performance improvement. The resulting performance and throughput improvements are deliberated in this paper.

BREAK **9:55 AM**

TA7-5 **10:15 AM**

Efficient FPGA Implementation of a High Throughput Systolic Array QR-Decomposition Algorithm

Matthias Abels, Till Wiegand, Steffen Paul, University of Bremen

In this paper we introduce an efficient FPGA implementation of a QR-decomposition algorithm, which is designed for a MIMO detector developed in view of the Long Term Evolution (LTE). The proposed architecture is based on a line-by-line systolic array structure and reaches the peak matrix throughput, which is required to achieve the defined LTE peak data rate of a 2x2 MIMO constellation using a 20 MHz transmission bandwidth. In the final paper we will describe the optimized architecture and FPGA implementation as well as the algorithm in detail and show the performance results of a Xilinx Virtex IV realization.

TA7-6 **10:40 AM**

Comparison of Performance and Implementation Complexity of Soft-Output Sphere Detectors for MIMO-OFDM Systems

Markus Myllyla, Renesas Mobile Europe Ltd

A list sphere detector (LSD) is a soft-output enhancement of a sphere detector (SD) that can be used to approximate the optimal MAP detector in the detection of the multiple-input multiple-output (MIMO) signals. The LSDs are based on tree search algorithms and they can be divided into three categories: the breadth-first (BF) search, the depth-first search (DF), and the metric-first (MF) search algorithms. A fair comparison of the feasibility of different search algorithms for MIMO detection requires efficient architecture designs and hardware implementations of the algorithms. In this paper, we compare and analyze the error rate performance, ASIC implementation complexity and detection rate of LSDs based on all three types of search strategies for 4x4 MIMO-OFDM systems with 16- and 64-QAM

TA7-7 **11:05 AM**

Time and Power Optimization in FPGA Based Architectures for Polyphase Channelizers

Mehmood Awan, Peter Koch, Aalborg University; Fredric Harris, San Diego State University

This paper presents time and power improvement considerations for FPGA (Field Programmable Gate Array) architectures for a polyphase filter bank channelizer with an embedded square root shaping filter in its polyphase engine. This configuration performs two different re-sampling tasks required for spectral shaping and for M-channel channelizer. A non-maximally decimated polyphase filter bank, where the number of data-loads is less than the number of sub-filters, requires larger processing time than the corresponding data-load time. In order to meet the time constraints, the polyphase engine has to run at a high clock rate and hence potentially consumes high power. Load-Process architectures presented in [1], modified with interlaced operations to reduce the required clock rates, and Run-Time Architectures operating only at twice the input data rate are presented in this paper in order to address clock rate and power optimization possibilities.

TA7-8 **11:30 AM**

Hardware Implementation of Kuiper-Based Modulation Level Classification

Paulo Urriza, Eric Rebeiz, Danijela Cabric, University of California, Los Angeles

A hardware implementation for a modulation level classifier based on a reduced complexity Kuiper test is presented and its performance is evaluated. In particular, the classification accuracy of the proposed architecture in distinguishing among 4, 16, and 64-QAM under varying SNR in a real hardware platform is investigated. The architecture is described, analyzed and compared to other techniques. Correct classification of QAM modulated signals is achieved with as little as 50 symbols in a 12dB SNR scenario with 85% accuracy at a hardware utilization that is significantly less than that of the popular Cumulant method and the recently proposed Kolmogorov-Smirnov technique. The effect of timing offset and imperfect pulse shape knowledge will be studied in the future.

Session: TAa8 – Signal Processing Methods for Representation, Analysis, and Control of Biological Systems 8:15 AM – 9:55 AM

Co-Chairs: ***Byung-Jun Yoon,*** *Texas A&M* ***and Xiaoning Qian,*** *University of South Florida*

TA8a1-1
Exact MSE Performance of the Bayesian MMSE Estimator for Classification Error

Lori A. Dalton, Edward R. Dougherty, Texas A&M University

Biomedicine is faced with difficult high-throughput small-sample classification problems, with classifier errors typically approximated using classical, though heuristically devised, resampling methods. A recently proposed Bayesian error estimator (BEE) places the problem in a signal estimation framework in the presence of uncertainty, resulting in a minimum-mean-square error solution, where uncertainty is relative to the parameters of the feature-label distribution and conditioned on the observed sample. Here, we derive the theoretical MSE for BEEs, demonstrating a unique advantage over resampling methods in that the mathematical framework of BEEs naturally gives rise to a practical expected measure of performance given a fixed sample.

TA8a1-2
Misaligned Principal Component Analysis (Mis-PCA) for Gene Expression Time Series Analysis

Arnau Tibau-Puig, Alfred O. Hero, University of Michigan

We consider the problem of estimating a signal subspace from noisy and misaligned observations. This problem arises in the context of multivariate time series analysis, where sampling times can not be synchronized across different observations, due to technical or physical limitations. The most popular approach for estimating a signal subspace is called Principal Component Analysis (PCA). Unfortunately, under the presence of unknown misalignments, PCA suffers from the fact that the observations are no longer characterized by the same covariance matrix. In this work we first study the effects of misalignment on the performance of the PCA estimators, both in the small and the large-dimensional setting. Motivated by our theoretical results, we propose the Misaligned PCA (Mis-PCA), an algorithm to jointly estimate the signal subspace and the misalignment parameters. We apply our methodology to the study of misaligned immune system responses of infected individuals from longitudinal gene expression data.

TA8a1-3
Optimal Intervention Strategies for Cyclic Therapeutic Methods with Fixed-Length Duration of Effect

Mohammadmahdi R. Yousefi, Aniruddha Datta, Edward R. Dougherty, Texas A&M University

In cancer treatment, mostly in the form of chemotherapy where therapies are given in cycles, the goal is to alter the likelihood of undesirable states such as those associated with disease in the long run. After delivery, the drug will be effective on the target cell(s) for some period of time, followed by a recovery phase. This paper finds an optimal cyclic intervention strategy with fixed-length duration of effect for any Markovian genetic regulatory network to provide an effective treatment plan.

TA8a1-4
Maximum Likelihood Estimation of the Binary Coefficient of Determination

Ting Chen, Ulisses Braga-Neto, Texas A&M University

The binary Coefficient of Determination (CoD) has been a key component of inference methods in Genomic Signal Processing. Assuming a stochastic logic model, we introduce a new sample CoD estimator based upon maximum likelihood (ML) estimation. Experiments have been conducted to assess how the ML CoD estimator performs in recovering predictors and functions in Boolean networks with perturbation. Performance is compared with the traditional nonparametric CoD estimators based on resubstitution and leave-one-out. The results show that the ML CoD estimator is the best estimator for large perturbation probability. This indicates that, provided one has prior information in the form of known logic regulatory relationships in the network, the proposed ML CoD estimator is to be preferred over nonparametric choices.

TA8a1-5
An MCMC Algorithm for Base Calling in Sequencing-by-Synthesis
Ting Wu, Haris Vikalo, The University of Texas at Austin

Sequencing-by-synthesis is a novel technology which enables fast and affordable DNA sequencing. However, its accuracy is insufficient for most medical applications. The performance of sequencing-by-synthesis is fundamentally limited by imperfections in the underlying enzymatic process. We derive a mathematical model of sequencing-by-synthesis and develop novel base calling methods that rely on Monte Carlo Markov Chain and iterative integer least squares techniques. Simulation and experimental results demonstrate superior performance of the proposed methods over the state-of-the-art base-calling techniques.

TA8a1-6
Relationships Between Genetic Regulatory Network Models
Mehmet Umut Caglar, Ranadip Pal, Texas Tech University

Selection of a model to represent a genetic regulatory network depends on the purpose of modeling, available experimental data and computational complexity of the model. Numerous approaches have been proposed for modeling of genetic regulatory networks. Some approaches may be suitable for specific analysis whereas they can perform poorly for another analysis. In this article, we discuss relationships between three important classes of models: fine-scale stochastic master equation models, coarse-scale Markov chain models and deterministic differential equation models. The transient and steady-state properties of the approximate models are analyzed and illustrated through biological examples.

TA8a1-7
Bayesian Networks Modeling of Cellular Regulatory Pathways
Chen Zhao, Ivan Ivanov, Texas A&M University; Michael Bittner, Translational Genomics Research Institute; Edward R. Dougherty, Texas A&M University

Modeling of Gene Regulatory Networks (GRNs) is a critical when designing effective intervention when cells are trapped in pathological modes of operation. The models have to capture sufficient detail of the network structure without being overly complex. The cellular regulatory pathways represent important components of GRNs. We employ a Bayesian tree model to characterize conditional pathway logic and quantify the effects of different branching patterns and signal transmission efficiencies. In particular, we characterize master genes and canalizing genes within the quantitative framework. The model is also used to examine what inferences about the network structure can be made when perturbations are applied to various points in the network.

TA8a1-8
Haplotype Inference Based on Sparse Dictionary Selection
Guido Hugo Jajamovich, Xiaodong Wang, Columbia University

The knowledge of the haplotypes of an individual makes it possible to predict diseases and help designing drugs. However, due to the cost of experimentally determining haplotypes, genotypes are usually measured instead. The haplotypes can still be inferred if the genotypes of a group of unrelated individuals are measured. We propose a mathematical framework and an efficient formulation based on the maximum parsimony principle that translates this principle as a sparse dictionary selection problem. We test the proposed solution with synthetic and real data sets and compare the performance with other methods.

TA8a1-9
Surface-Constrained 3D Reconstruction in Cryo-EM
Andrew C. Barthel, Hemant Tagare, Fred J. Sigworth, Yale University

Random spherically-constrained (RSC) reconstruction is a new form of single particle reconstruction (SPR) using cryo-EM images of membrane proteins embedded in spherical lipid vesicles to generate a 3D protein structure. The method has many advantages over conventional SPR, including a more native environment for protein particles and an initial estimate of the particle's angular orientation. These advances allow us to determine structures of membrane proteins such as ion channels and derive more reliable structure estimates. We present an algorithm that relates conventional SPR to the RSC model, and generally, to projection images of particles embedded with an axis parallel to the local normal of a general 2D manifold. We illustrate the performance of this algorithm in the spherical system using synthetic data.

TA8a1-10
Phenotypically Constrained Stationary Control Policies for Gene Regulatory Network Intervention
Xiaoning Qian, University of South Florida; Edward R. Dougherty, Texas A&M University

Developing intervention strategies based on computational network models of gene regulatory networks is one of the key objectives in systems biology. While previous optimal and approximate intervention strategies focus on the single objective of reducing the risk of entering aberrant phenotypes, we propose phenotypically constrained stationary control policies based on probabilistic Boolean networks to restrict possible collateral damage introduced by these single-objective intervention strategies. These new constrained control policies directly study the long-run network behavior via the steady-state distribution of the underlying Markov chain. By imposing the constraints for the redistributed steady-state mass after intervention, these policies can limit collateral damage as well as reducing the total steady-state mass of undesirable states. Preliminary results from synthetic and biological networks have demonstrated the effectiveness of the new constrained control policies.

TA8a1-11
Prediction of Cancer Subtypes Using Bayesian Factor Network Model
Jia Meng, The University of Texas at San Antonio; Manuel Sánchez Castillo, University of Granada; Jianqiu Zhang, The University of Texas at San Antonio; Isabel María Tienda Luna, University of Granada; Yufei Huang, The University of Texas at San Antonio

Developing accurate cancer prognosis approaches based on molecular profiling such as mRNA expression profiles of patients are at the forefront of cancer biomedical research. With these approaches, disease subtypes are determined first and molecular profile signatures are then identified for each subtype for predicting the treatment response and the survival of patients. Despite great promise of this research, advancements in mRNA profiling have produced little effectively signature markers for cancer and other disease. A major problem is the ill robustness of the signature, thanks mainly to the excessive noise in mRNA profiling data. In this work, we apply a Bayesian network factor model that projects high dimensional mRNA expression data onto the low dimensional space of transcription factor activities by integrating the prior knowledge of transcription factor mediated regulatory networks. This projection effectively removes the noise and interference embedded in the mRNA expression data, making the cancer subtype prediction based on transcription factor activities much more effective than mRNA expression. To further improve the subtype prediction performance of the conventional sequential procedure, this model performs cancer subtypes prediction jointly with the projection. The model is applied to breast cancer expression profile data to identify new subtypes that have distinct survival outcomes.

TA8a1-12
Dynamical Processes on Networks: A Unified View
Garrett Jenkinson, John Goutsias, The Johns Hopkins University

The study of complex networks has uncovered many unifying topological principles from a plethora of apparently unrelated applications. Progress has been slower in understanding the dynamical processes taking place on networks. The difficulty arises largely from the diversity of applications and their inherent nonlinearities. In this paper, we demonstrate that biochemical reaction networks may serve as a unifying framework for both stochastic and deterministic processes on networks from diverse scientific fields, such as cell biology, pharmacology, neurology, epidemiology, ecology, and sociology. This allows the use of advanced techniques for the modeling, reverse engineering, and analysis of chemical reaction networks to be applied to wide-ranging applications with relative ease.

TA8a1-13
A Brief Review of Signal Processing Issues in Mass Spectrometry-Based Proteomics Studies
Chao Yang, Weichuan Yu, Hong Kong University of Science and Technology

Mass spectrometry (MS) is frequently used in proteomics to conduct high-throughput experiments. In MS data analysis, low level signal processing tasks such as denoising, baseline correction and peak detection are involved to extract peptide related information for subsequent analysis. In the literature, numerous preprocessing methods have been described. We give a brief review of preprocessing methods and illustrate signal processing issues in MS data analysis.

TA8a1-14
Fault Detection and Intervention in Biological Feedback Networks
Ritwik Layek, Aniruddha Datta, Texas A&M University

Diseases like cancer require modeling of the genetic regulations and the loss of control in it. Is has been seen that the genetic alterations in the system can be suitably modeled using different fault models (like stuck-at faults) in the Boolean Network paradigm. Understanding the dynamics of the original and the faulty BN, it is possible to design drug intervention strategies which can drive the system from diseased to normal state. In the current work, the method of detecting faults along with the intervention design is shown for some real biological pathways (DNA damage pathways and osmotic stress response pathways).

TA8a1-15
Fast Global Sequence Alignment Algorithm
Talal Bonny, Khaled Nabil Salama, King Abdullah University of Science and Technology

Optimal sequence alignment tools are considered both time consuming and extensive computationally. Thus heuristic algorithms are used to provide approximate but fast close to optimal results. We introduce a new fast alignment algorithm, named `Alignment By Scanning' (ABS), to provide an approximate alignment of two DNA sequences. We compare our algorithm with the well-known alignment algorithms, the "GAP" (which is heuristic) and the "Needleman-Wunsch" (which is optimal). Our ABS algorithm achieves more accurate results than the GAP and is close to the optimum results obtained form the Needleman-Wunsch Algorithm. We also show that it runs in time linear to the sequence length (O(n)) compared to the GAP or the Needleman-Wunsch algorithm that run in time proportional to the product of sequence lengths (O(m × n)).

TA8a1-16
Optimal State Estimation for Boolean Dynamical Systems
Ulisses Braga-Neto, Texas A&M University

We propose a novel approach for optimal state estimation for discrete-time Boolean dynamical systems, i.e. dynamical systems based on switching elements, where the state vector is binary and the transition functions are Boolean logic functions, under noisy observational conditions. We discuss in the paper exact solution methods for the optimal state estimator, and discuss applications to Genomic Signal Processing.

Track A. Communications Systems
Session: TAa8 – Receiver Design and Optimization 8:15 AM – 9:55 AM
Chair: ***Lara Dolecek,*** *UCLA*

TA8a2-1
Incorporating Prior Information into Semi-Definite Relaxation of Quadratic Optimization Problems
Jacob (Jake) Gunther, Todd Moon, Utah State University

This paper focuses on equalization as a representative of the large class of communications receiver problems that can all be cast as the optimization of a quadratic objective function subject to quadratic constraints (QCQP problems). It is well known that approximate solutions to QCQP problems can be obtained efficiently through a relaxation technique which results in a linear program subject to a semidefinite constraint. This paper extends the semidefinite relaxation (SDR) approach to incorporate prior probabilities on the bits. With this extension, the SDR approach may used in the setting of turbo equalization and in other forms of iterative receiver processing. In this paper, the soft-in soft-out SDR-based equalizer is compared to an optimal maximum a posteriori probability based equalizer implemented via the BCJR algorithm.

TA8a2-2
Diversity of the MMSE Receiver in Flat Fading and Frequency Selective MIMO Channels at Fixed Rate
Florian Dupuy, Thales Communication / Université Paris Est; Philippe Loubaton, Université Paris Est

In this contribution, the evaluation of the diversity of the MIMO MMSE receiver is addressed for finite rates in both flat fading channels and frequency selective fading channels with cyclic prefix. It has been observed recently that in contrast with the other MIMO receivers, the MMSE receiver has a diversity depending on the aimed finite rate, and that for sufficiently low rates the MMSE receiver reaches the full diversity - that is, the diversity of the ML receiver. This behavior has so far only been partially explained. The purpose of this paper is to provide complete proofs for flat fading MIMO channels, and to improve the partial existing results in frequency selective MIMO channels with cyclic prefix.

TA8a2-3
Predicting the Pruning Potential on the Sphere Decoding for Multiple-Input Multiple-Output Detection

Hwanchol Jang, Gwangju Institute of Science and Technology; Saeid Nooshabadi, Michigan Technological University; Heung-No Lee, Gwangju Institute of Science and Technology

In this paper, the way of predicting the pruning potential of the sphere constraint (SC) is developed. This makes it possible to increase the prunings near the root of the search tree. To ease the pruning potential prediction, the SC is replaced by the orthotope constraint (OC). The notion of unavoidable constellation points is introduced as a tool to predict the pruning potential of a sphere constraint (OC).

TA8a2-4
Computationally Efficient Design of the MAE Equalizer for Binary Signaling

Weiwei Zhou, Jill Nelson, George Mason University; Ananya Sen Gupta, Woods Hole Oceanographic Institution

This paper proposes a computationally efficient approach to designing the maximum asymptotic efficiency (MAE) equalizer, which minimizes bit error rate as signal-to-noise ratio approaches infinity. The MAE equalizer is implemented as a tapped delay line and hence has the same runtime complexity as the simple MMSE linear equalizer. However, design of the MAE equalizer involves finding the minimum distance between two convex hulls. Its design complexity is exponential in the channel and equalizer lengths, making it impractical for long channels. The proposed method exploits the relationship between the channel vectors and the convex hull formed by the noise-free channel outputs to design the MAE equalizer directly from the channel coefficients without requiring a search of the convex hull.

TA8a2-5
Broadband Doppler Compensation: Principles and New Results

Thomas Riedl, Andrew Singer, University of Illinois, Urbana-Champaign

The underwater acoustic channel is particularly challenging for high-data-rate digital communications due to its large delay spread and rapid time variation. The transmitted signal bandwidth is also a substantial fraction of its center frequency, such that platform mobility gives rise to Doppler effects manifested as time-varying temporal scaling of the waveform. This paper develops a novel Doppler compensation method that recursively tracks the optimal (in an approximate MMSE sense) resampling of the received waveform. Performance on real ocean acoustic data verify an order of magnitude improvement over existing gross-Doppler plus phase-locked-loop methods.

TA8a2-6
Optimal Pilot Symbol Power Allocation in Multi-Cell Scenario in LTE

Michal Simko, Markus Rupp, Vienna University of Technology

The UMTS Long Term Evolution (LTE) allows the pilot symbol power to be adjusted with respect to that of the data symbols. In this paper, we derive optimal pilot power allocation in multi-cell scenario under imperfect channel knowledge at the terminals. As optimization function, we choose the post-equalization Signal to Interference and Noise Ratio (SINR).

TA8a2-7
On the Ergodic Secrecy Capacity of the Wiretap Channel under Imperfect Main Channel Estimation

Zouheir Rezki, King Abdullah University of Science and Technology; Ashish Khisti, University of Toronto; Mohamed-Slim Alouini, King Abdullah University of Science and Technology

The ergodic secrecy capacity of the wiretap channel is known when the main channel (between the transmitter and the legitimate receiver) state information (CSI) is perfect at the transmitter, but for sufficiently large coherence period. In a fast fading scenario, when the codeword length spans many coherence periods, the secrecy capacity is still not known. In this paper, we present a framework that characterizes this secrecy capacity under imperfect main channel estimation at the transmitter. Inner and outer bounds on the ergodic secrecy capacity are derived for a class of independent identically distributed (i.i.d.) fading channels. The achievable rate is a simple on-off scheme using a Gaussian input. The upper bound is obtained using an appropriate correlation scheme of the main and the eavesdropper channels, and is the best known upper bound so far. The upper and the lower bounds coincide with recently derived ones in the perfect main CSI extreme. Furthermore, the lower bound matches the upper bound in no main CSI extreme, where the secrecy capacity is equal to zero. Numerical results are provided for independent identically distributed (i.i.d.) Rayleigh fading channels.

TA8a2-8
On the Stability of DSP Based PI Phase-Locked Loops Containing Matched Filter Delays
Fredric Harris, San Diego State University; Behrouz Farhang-Boroujeny, University of Utah

Phase locked loops (PLL) are designed to align the frequency and the phase of the PLL phase accumulator with the frequency and phase of a complex sampled data input sinusoid. When the PLL is required to align the phase slope and phase of the local DDS with the phase slope and phase of a suppressed carrier modulated input signal the PLL phase detector must be augmented by a non-linear process that forms the underlying carrier. A common process estimates the instantaneous envelope of the modulated waveform and removes the modulation to expose the underlying carrier. Reliable estimates of the modulation are formed with the aid of a matched filter and an auxiliary timing recovery process. The matched filter process occurs inside the PLL loop and contributes additional loop delay. Delay inside a feedback loop is undesirable since it tends to destabilize the loop. We examine the effect of this excess loop delay and present intuitive design constraints that assure loop stability.

Track A. Communications Systems
Session: TAa8 – Communications System Design 8:15 AM – 9:55 AM
Chair: ***Marco Chiani,*** *University Bologna*

TA8a3-2
An SDR Architecture for OFDM Transmission over USRP2 Boards
Gilberto Berardinelli, Aalborg University; Per Zetterberg, KTH Royal Institute of Technology; Oscar Tonelli, Andrea F. Cattoni, Troels B. Sørensen, Preben Mogensen, Aalborg University

The Universal Software Radio Peripheral (USRP) developed by Ettus research is emerging as a promising hardware solution for building a Software Defined Radio (SDR) platform. In this paper we discuss the implementation of a coded Orthogonal Frequency Division Multiplexing (OFDM) transceiver running over USRP2 boards. The baseband processing and the radio-frequency settings are designed for coping with a local area scenario as well as with the physical capabilities of the USRP2 boards. Moreover, a simple subcarrier blinding algorithm is proposed with the aim of compensating the common phase error in the symbol constellation due to the noisy local oscillators.

TA8a3-3
Environmental-Aware Heterogeneous Partial Feedback Design in a Multi-User OFDMA System
Yichao Huang, Bhaskar D. Rao, University of California, San Diego

We propose a heterogeneous feedback design method which adapts users' feedback resources to their frequency domain channel statistics. We analytically demonstrate the potential of this environmental-aware feedback design in a multiuser OFDMA scheduling framework employing the best-M partial feedback strategy. We derive an expression for the average spectral efficiency of the system, and utilize suitable approximations to obtain the minimum heterogeneous partial feedback required for minimal degradation in performance compared to a scheme using full feedback. Our heterogeneous feedback design is shown to outperform the traditional homogeneous one under a fixed feedback resource constraint.

TA8a3-4
Adaptive OFDM for Underwater Acoustic Channels with Limited Feedback
Andreja Radosevic, University of California, San Diego; Tolga Duman, Arizona State University; John Proakis, University of California, San Diego; Milica Stojanovic, Northeastern University

In this paper we analyze the performance of adaptive orthogonal frequency division multiplexing (OFDM) for underwater acoustic (UWA) communications. Our goal is to maximize the system throughput under a target average bit error rate (BER). We consider two different schemes based on the level of adaptivity: in the first scheme only the modulation levels are adjusted while the power is allocated uniformly across the sub-carriers, whereas in the second scheme both, the modulation levels and the power are adjusted adaptively. We predict the channel one travel time ahead so as to improve the performance in the presence of a long propagation delay. The effectiveness of the proposed schemes is demonstrated using real channel measurements recorded in shallow water off the western coast of Kauai, Hawaii, in June 2008.

TA8a3-5
A 512-Point 8-Parallel Pipelined Feedforward FFT for WPAN
Tanvir Ahmed, Mario Garrido, Oscar Gustafsson, Linköping University

This paper presents a 512-point feedforward FFT architecture for wireless personal area network (WPAN). The architecture processes a continuous flow of 8 samples in parallel, leading to a throughput of 2.64 GSamples/s. The FFT is computed in three stages that use radix-8 butterflies. This radix reduces significantly the number of rotators with respect to previous approaches based on radix-2. Besides, the proposed architecture uses the minimum memory that is required for a 512-point 8-parallel FFT. Experimental results show that besides its high throughput, the design is efficient in area and power consumption, improving the results of previous approaches. Specifically, for a wordlength of 16 bits, the proposed design consumes 79 mW and its area is 1.57 mm^2.

TA8a3-6
On the Convergence of Joint Channel and Mismatch Estimation for Time-Interleaved Data Converters
Sandeep Ponnuru, Upamanyu Madhow, University of California, Santa Barbara

Mostly digital architectures for communication transceivers rely on the use of accurate analog-to-digital converters (ADCs), which becomes a bottleneck in scaling to multiGigabit speeds. A promising workaround is to employ slower, power-efficient sub-ADCs in a time-interleaved ADC (TI-ADC) architecture. While mismatch between sub-ADCs can lead to performance floors, recent work shows that this can be mitigated using joint channel and mismatch compensation algorithms. In this paper, we investigate the scalability and convergence of a recently proposed iterative channel and mismatch estimation algorithm, and derive rules of thumb relating the required length of training to the number of sub-ADCs.

TA8a3-7
Comparison of Energy- and Spectral-Efficient Design for LTE Downlink Systems
Liying Li, University of Electronic Science and Technology of China; Jiancun Fan, Xi'an Jiaotong University; Gang Wu, Hongbing Xu, University of Electronic Science and Technology of China; Geoffrey Ye Li, Georgia Institute of Technology

In this article, we investigate energy-efficient (EE) power control and resource allocation for LTE downlink systems. Since EE optimization to satisfy all practical constraints of LTE systems is extremely complicated, we develop suboptimal and low-complexity approaches for EE based design and compare with that of spectral-efficient (SE) design. We will demonstrate that EE design maintains high throughput while the spectral-efficiency design results in huge energy-efficiency degradation even through it reaches maximum throughput. Therefore, energy-efficient design is better than spectrum-efficient design for LTE downlink systems.

TA8a3-8
An Efficient Cascade of Half-Band Filters for Software Defined Radio Transmitters
Fredric Harris, Xiaofei Chen, Elettra Venosa, San Diego State University

Power consumption is an important issue in the software defined radio transmitter and receiver. In this paper we present a technique that aliases the signal from base-band to its desired center frequency by a sequence of 1-to-2 up-sampling half-band filters. Each stage of the proposed structure is formed by a half-band filter embedded in a 4-path polyphase engine with center frequencies aligned with the 4-cardinal directions. By judicious choice of the appropriate filter the proper alias of the 1-to-2 up sampled input signal is passed to the next stage for further up-sampling and alias shifting. The number of stages in the cascade is optimized according to the half-band filter design constraints and the desired output sampling frequency. An initial frequency offset is applied at the low input sample rate by a complex heterodyne prior to the frequency shifting process provided by the cascade of aliased half-band up-sampling operations. A 1-of-4 selection process guides the input spectrum to extract the spectral alias of the appropriate center frequency path at each stage to place the final alias at the desired frequency location. The paper provides comparisons and detailed workload analyses that motivate the selection of the proposed structure among the others available which are good candidates for accomplishing the same tasks. Simulation results are presented at the end of the paper for supporting the theoretical results.

Session: TAa8 – Applications of Array Processing 8:15 AM – 9:55 AM

Chair: ***Giuseppe Abreu,*** *Oulu University, Finland*

TA8a4-2

Detection Properties of Some Sparse Representation Approaches

Jean Jacques Fuchs, Université de Rennes 1

When used to solve inverse problems, sparse representations algorithms often achieve simultaneously a detection and a estimation task. For the detection part, the choice of the criterion among equivalent ones from an optimization point of view, is then crucial since equivalent optimization criteria correspond to quite different detection strategies. It is established that tuning the bounds or the hyper-parameters in these criteria is equivalent to fixing the thresholds in different detection schemes whose statistical properties (receiver operating characteristics) are far from being the same. It is indicated which criterion should be retained, how to scale its formulation, how to tune its hyper-parameter and eventually how to unbias the resulting estimates.

TA8a4-3

Estimating Bridge Displacement from Acceleration Using Modal Analysis and the Minimum Description Length Principle

Viswanadh Kandula, Linda S. DeBrunner, Victor DeBrunner, Michelle Rambo-Rodenberry, Florida State University

Measuring bridge displacement for moving vehicle loads helps in load rating and evaluating the structural health of the bridge. Traditional methods of measuring bridge displacement such as laser systems and displacement transducers are expensive, require a stationary reference point, and are complicated to setup. Accelerometers are inexpensive and easy to use, but direct double integration gives unacceptable results. We use minimum description length to remove the noise from the acceleration and obtain correct displacement estimation using modal analysis. We also show how the static displacement can be obtained. The effectiveness of our proposed method is confirmed in laboratory testing.

TA8a4-4

Non-Uniform Sparse Array Design for Active Sensing

Ching-Chih Weng, P. P. Vaidyanathan, California Institute of Technology

Active sensing using multiple transmitting elements and independent waveforms has recently attracted much attention. Using M transmitting and N receiving elements, one can virtually simulate a physical array of MN elements by the sum co-array. Nonuniform sparse arrays can further be used in active sensing to produce the difference co-array of the given sum co-array with dramatically increased degree of freedom. However, current literature lacks an efficient design method for active sensing with nonuniform sparse arrays. In this paper, we address this problem and propose several systematic construction methods based on some classical results in number theory. By using these methods, we are able to construct active sensing sparse arrays, in which the difference co-array of the sum-co-array has aperture in the order of $O(M^2N^2)$. Furthermore, it has no holes within this aperture. Several performance bounds on the maximum aperture of the sparse array are then provided. These can be used in the future to compare the performance of other suboptimal nonuniform sparse array geometries.

TA8a4-5

MIMO Radar Target Measurements

Kyle Stewart, Mark Frankford, Joel Johnson, Emre Ertin, Ohio State University

Evaluation of an extended statistical model for the representation of realistic targets in a MIMO radar system is conducted. Objects are modeled by a finite area filled with an infinite number of point-source scatterers whose amplitudes are correlated as a function of spatial proximity. Testing of this model was conducted against both numerically simulated data and radar measurements from the OSU software-defined radar platform. The inclusion of correlation distance is evaluated for its utility in describing the average radar profile of realistic targets, and its effects on the detection performance of simulated MIMO systems is further analyzed.

TA8a4-6
Efficient Removal of Noise and Interference in Multichannel Quadrupole Resonance
Naveed Razzaq Butt, Andreas Jakobsson, Lund University

We present an improved multichannel detection algorithm for use in nuclear quadrupole resonance (NQR) applications. The presented method exploits spatial diversity and additional noise-only data to efficiently remove spatially and temporally correlated noise and interference components from the measured data. Numerical investigations indicate that the “cleaner” data, thus obtained, allows for improved estimates of the NQR signal parameters. These improved estimates, in turn, lead to superior detection performance compared to the current state-of-the-art multichannel algorithms.

TA8a4-7
Time Reversal Bayesian Ultrasonic Array Imaging for Non-Destructive Testing
Foroohar Foroozan, Nasim Moallemi, Shahram ShahbazPanahi, University of Ontario Institute of Technology

In ultrasonic non-destructive testing (NDT), it is desirable to have as much information as possible about the size and shape of a defect. But due to the reflections from numerous dispersive modes and the mode conversion that occurs at the defects, the resulting images become very difficult to interpret. Our objective in this paper is to use time reversal (TR) coupled with the Bayesian estimation framework for NDT applications, in order to compensate for dispersive and multi-modal effects of the acoustic waves. We present a linear acoustic model for imaging using TR and reconstruct the image using time reversal linear beamformer which minimizes the overall image reconstruction error in a mean square sense. TR shows a potential for reducing false target locations due to multi-modal effects, which is verified by our numerical simulations conducted using the DREAM software.

TA8a4-8
Energy-Efficient MMSE Beamforming and Power Optimization in Multibeam Satellite Systems
Gan Zheng, Symeon Chatzinotas, Björn Ottersten, SnT, University of Luxembourg

In current satellite communication systems, energy efficiency is of paramount importance since it strongly affects the satellite lifetime. In this paper, the energy efficiency of a multibeam downlink system is investigated in terms of minimizing the average required transmit power for fading channels to match the traffic demand, in contrast to most of the existing joint beamforming design based on a fixed channel state. MMSE beamforming together with power optimization for satellite downlink channel is used while full frequency reuse is assumed. The efficiency gain of this transmission technique is demonstrated by comparison with a conventional 4-color multibeam system.

TA8a4-9
Equidistributed Sampling Sequences for Spectral Analysis
Mustafa Al-Ani, Andrzej Tarczynski, University of Westminster

In this paper we propose a sampling scheme for alias-free spectral analysis of signals. Unlike classical similar approaches, the scheme uses deterministic rather than random sampling. The properties of the generated sampling sequences resemble those of the random sampling ones in the sense of suppressing/reducing aliasing. Nonetheless, the endorsed scheme is shown to be more efficient and is better suited to practical implementation. It is demonstrated that for signals with bounded variations, the error in the obtained spectrum from N number of samples is bounded and can decay at the rate of log(N)/N.

Session: TAb8 – Multiple Antennas in Multi-User Systems and Networks 10:15 AM – 12:00 PM

Chair: ***Shuguang Cui,*** *Texas A&M University*

TA8b1-2
Maximum-Likelihood Decoding in Decode-and-Forward Based MIMO Cooperative Communication Systems

Ankur Bansal, Manav Bhatnagar, Indian Institute of Technology, Delhi; Are Hjørungnes, UNIK, University of Oslo; Zhu Han, University of Houston

We derive a maximum-likelihood (ML) decoder for a multiple antenna based decode-and-forward (DF) cooperative system utilizing an arbitrary complex-valued M-ary constellation. A sub-optimal piece-wise linear (PL) decoder is also derived, which works close to the ML decoder with significant reduction in decoding complexity. The proposed ML and PL decoders work for arbitrary complex-valued M-ary constellations with knowledge of the channel statistics of the source-relay links in the destination contrary to existing decoder of multi-antenna DF based systems which needs to know the exact source-relay channel coefficient. The proposed decoders outperform an amplify-and-forward protocol based multi-antenna cooperative system. We also derive the analytical symbol error rate (SER) of the PL decoder with multiple relays, M-PSK constellation, and asymptotically high signal-to-noise ratio (SNR) of the source-relay links.

TA8b1-3
Complex Interference Optimization for Power Loss Reduction in MIMO-THP Transmission

Christos Masouros, Mathini Sellathurai, Tharmalingam Ratnarajah, Queen's University Belfast; Ying-Chang Liang, Institute for Infocomm Research

In this paper, we investigate a novel strategy for reducing the power loss in multiple-input multiple-output Tomlinson-Harashima precoding (MIMO-THP), based on optimizing the interference to be modulo-subtracted. The concept behind the proposed technique builds on the fact that both the desired and interfering signals originate from the base station (BS) of the downlink system itself. Based on this observation, the proposed method influences the amplitude and phase of the resulting interference, to reduce the transmission power required to cancel it, without altering the information content of the downlink message. The aim is to bring the interference closer to the replicas of the desired symbols for all users in the THP modulo-extended constellation. In this way, the power required to pre-subtract interference is decreased. The effect of the interference optimization is studied by means of mathematical analysis where the Gaussian-Modulo distribution is derived, and used to model the THP-precoded symbols and analytically calculate the resulting power loss. A close match between theoretical and simulation results is shown, while both confirm that the proposed technique offers a considerable transmit power reduction compared to conventional THP for an equal error rate performance.

TA8b1-4
Channel Tracking for D-BLAST for Airborne Platforms

Kapil Borle, Biao Chen, Syracuse University; Michael Gans, Air Force Research Laboratory

Coherent symbol detection requires knowledge of channel state information. The traditional use of embedding pilot symbols with payload data may not be easy to justify if channel variation is fast and/or data rate requirement is high. We consider the implementation of D-Blast for airborne platforms and develop channel tracking scheme that eliminate or reduce the use of pilot symbols. In a normal operation mode, channel update is achieved dynamically as each layer of the D-Blast, encoded using an LDPC code, is decoded. To ensure that the transceiver can detect outage due to the loss of channel state, an adaptive algorithm is devised utilizing the extremal property of terminating likelihood ratio of an LDPC decoder.

TA8b1-5
Interference Alignment for Multiple-Antenna Amplify-and-Forward Relay Interference Channel

Kien T. Truong, Robert W. Heath, Jr., The University of Texas at Austin

Relay networks are sensitive to interference. Interference alignment is a technique recently shown to achieve the maximum number of degrees of freedom the single-hop interference channel. Unfortunately, prior work on relay interference channel has focused mainly on the networks with either a single shared relay or an asymptotically large number of relays. In this work, we

develop interference alignment algorithms for the multiple-antenna amplify-and-forward relay interference channel with not many relays. All the nodes are equipped with multiple antennas. Numerical results show how the algorithms are useful and give insight into the limitations of relay-aided interference alignment.

TA8b1-6
On the Instantaneous Degrees of Freedom of Downlink Interference Channel with Multiuser Diversity

Taejoon Kim, David Love, Purdue University; Bruno Clerckx, Samsung Electronics

We investigate the feasibility of linear processing in two-cell MIMO network. The network is composed of two homogeneous cells where in each cell there are K users. Each base station has N antennas and each user is equipped with M antennas. The linear processing we are considering includes zero-forcing and interference alignment. Interference alignment aims to allow coordinated transmission and reception in order to generate overlapping user signal spaces occupied by undesired interference while keeping the desired signal spaces distinct. In a time or frequency varying channel, interference alignment can be accomplished with symbol extension. In this work our main concern for interference alignment is using the spatial degrees of freedom with a constant channel coefficient assumption (instead of considering time or frequency domain symbol extension). We present an interference alignment scheme that enables us to resolve nonzero interference free signal dimensions to each of users and present the necessary condition for the number of antennas for the null space interference alignment.

TA8b1-7
On Grouped OFDM-IDMA

Jian Dang, Southeast University; Liuqing Yang, Colorado State University; Zaichen Zhang, Southeast University

A generalized version of orthogonal frequency division multiplexing interleave division multiple access (OFDM-IDMA) referred to as grouped OFDM-IDMA (G-OFDM-IDMA) is introduced in this paper. By dividing the users into several groups and transmitting each group's data only on part of the subcarriers, the G-OFDM-IDMA system can have much lower complexity compared with the conventional OFDM-IDMA while preserving the bandwidth efficiency and the bit error rate (BER) performance. We study the performance of the proposed scheme in terms of the decoding complexity and diversity order. We also extend the results to the multiple receive antennae case. Simulations are performed to corroborate the performance of our G-OFDM-IDMA.

TA8b1-8
Coordinated Multi-Cell Beamforming for LTE-Advanced Systems

Qixing Wang, Guangyi Liu, China Mobile Research Institute; Shuguang Cui, Texas A&M University

LTE-Advanced systems are built upon the orthogonal frequency division multiple access (OFDMA) technology, which can effectively eliminate the intra-cell interferences, but still cannot automatically mitigate the inter-cell interferences (ICI). Coordinated multi-point transmission/reception (CoMP) is one of the candidate enhancement techniques for LTE-Advanced systems to increase the average cell throughput and the cell-edge user throughput in both uplink and downlink transmissions by jointly managing the inter-cell interferences. Although CoMP may incur more system complexity, it potentially could lead to significant capacity and coverage benefits, which makes it worth more detailed investigation. In this extended abstract, we focus on the downlink multi-point coordinated beamforming (CoMP-CBF), and study a particular multi-stream beamforming scheme. We then present detailed system level performance evaluation of the proposed scheme against a reference LTE Rel.8 non-cooperative scheme, which shows that CoMP-CBF transmission could achieve significant gains on both the average cell throughput and the cell-edge user throughput.

TA8b1-9
Linear Transceiver Design for Interfering Broadcast Channel with QoS Constraints

Meisam Razaviyayn, Zhi-Quan Luo, University of Minnesota

Consider a MIMO interfering broadcast channel (multi-cellular network) where each base station transmits signals to the users in its own cell. An interesting basic problem is to design linear transmit/receive beamformer that can minimize the total power consumption of the base stations, while respecting the QoS constraints. In this work, we study the computational complexity of this problem and show that it is an NP-hard problem. Moreover, we propose a distributed algorithm for linear transmit/receive beamformer design.

TA8b1-10
Cooperative Feedback for MIMO Interference Channels
Kaibin Huang, Yonsei University; Rui Zhang, National University of Singapore

Multi-antenna precoding effectively mitigates the interference in wireless networks. However, the precoding efficiency can be significantly degraded by the overhead due to the required feedback of channel state information (CSI). This paper addresses such an issue by proposing a systematic method of designing precoders for the two-user multiple-input-multiple-output (MIMO) interference channels based on finite-rate CSI feedback from receivers to their interferers, called cooperative feedback. Specifically, each precoder is decomposed into inner and outer precoders for nulling interference and improving the data link array gain, respectively. The inner precoders are further designed to suppress residual interference resulting from finite-rate cooperative feedback. To regulate residual interference due to precoder quantization, additional scalar cooperative feedback signals are designed to control transmitters' power using different criteria including applying interference margins, maximizing sum throughput, and minimizing outage probability. Simulation shows that such additional feedback effectively alleviates performance degradation due to quantized precoder feedback.

TA8b1-11
Eigen-Mode Transmission for Jointly Correlated MIMO Broadcast Channels
Xiao Li, Shi Jin, Xiqi Gao, Southeast University

In this paper, we investigate the ergodic sum rate and present low complexity transceiver designs for the multiple-input multiple-output (MIMO) broadcast channels (BC) under jointly correlated fading. We assume that each user has perfect channel state information (CSI), while the base station only has access to each user's statistical CSI. Eigen-mode space division multiple access transmission is derived through the maximization of the sum rate. We also derive new closed-form upper bounds on the sum rate of the eigen-mode transmission system. Based on these upper bounds and the property of matrix permanent, we propose two eigen-mode power allocation algorithms which are shown to perform well and require the base station only to have the statistical CSI of each user.

TA8b1-12
How Many Degrees of Freedom Can Be Achieved for Mutually Interfering MIMO Broadcast Channels?
Hyukjin Chae, Sungyoon Cho, Kaibin Huang, Dongku Kim, Yonsei University

In this paper, we investigate degrees of freedom (DOF) for mutually interfering broadcast channels (IFBC) using linear transceivers. An achievable DOF for the MIMO IFBC is derived. Generalizing the downlink interference alignment (D-IA) which is proposed by Suh et al. in [1], we formulate the condition of D-IA for the general IFBC and check the feasible condition. The formulated equations can be considered as multivatriate polynomial system, which is solvable if and only if the number of equations does not exceed the number of variables that known as Bezouts theorem. Using the theorem, we find out an achievable DOF for the general IFBC with satisfying the feasible condition. We also figure out that the DOF of IFBC is greater than or equals to that of interference channels. A designing method of transceivers to achieve the DOF for the IFBC is also proposed.

TA8b1-13
Distributed Beamforming Based Directional Spectrum Sharing
Juan Liu, Wei Chen, Zhigang Cao, Tsinghua University; Ying Jun Zhang, Chinese University of Hong Kong

As an important multi-antenna technique, beamforming can be applied to enable concurrent transmissions of Secondary Users (SUs) and Primary Users (PUs) in Cognitive Radio (CR) systems. In this way, new transmission opportunities when the channel is occupied by PUs, namely spatial or directional spectrum holes, are exploited. This paper proposes a distributed beamforming approach for directional spectrum sharing to improve the Quality-of-Service (QoS) of SUs in CR systems. In particular, a SU source broadcasts to a set of cognitive nodes that act as SU relays, which can form a distributed beamformer to forward messages in busy timeslots without causing harmful interference to PUs. By doing so, both cooperative diversity gain and power gain are achieved without consuming extra idle timeslots or temporal spectrum holes. To support various secondary traffics with different arrival patterns, we develop a series of distributed beamforming based opportunistic spectrum access schemes. Through rigorous analysis, we analyze the system performance in terms of the delay-limited outage probability, the average delay and average throughput etc. Furthermore, cross-layer optimization problems are formulated to optimize the system performance by selecting appropriate scheduling parameters. A substantial QoS gain can be obtained by distributed beamforming based directional spectrum sharing, compared to those without node cooperation or cooperative diversity schemes utilizing temporal spectrum holes only.

TA8b1-14
Spatially Efficient Distributed Relay Selection for Random Relay Networks
Sungrae Cho, Wan Choi, Korea Advanced Institute of Science and Technology; Kaibin Huang, Yonsei University

In the presence of a large number of relays, some effective relays close to the source and destination nodes need to be regionally elected and the relays far from them shall be disregarded for relay selection process because of the likelihood of higher outage probability. In this paper, we propose an opportunistic feedback mechanism joining a geographical selection region where the relay whose effective channel gain is above a pre-determined threshold can only feedback, and thereby establish a relation between required relay-node density and the level of feedback threshold. It is shown that required relay-node density and selection region for a desired QoS depend on the feedback threshold.

TA8b1-15
Channel State Information Feedback Control for Interference Alignment
Lingyang Song, Peking University; Zhu Han, University of Houston; Shaohui Sun, Datang Mobile; Bingli Jiao, Peking University

It has been well recognized that channel state information~(CSI) feedback is extremely important for dowlink transmissions of interference alignment schemes. However, the existing work typically researched the CSI feedback problem for each individual mobile station~(MS), and thus, cannot efficiently model the interactions among self-interested mobile users in the network level. To this end, in this paper, we propose an alternative approach to investigate the CSI feedback rate control problem in the analytical setting of a game theoretic framework, in which multiple-antenna base stations~(BSs) communicate with a number of co-channel MSs through linear precoder. Specifically, we first present a non-cooperative feedback-rate control game~(NFC), in which each MS selects the feedback rate to maximize its performance in a distributed way. To improve efficiency from a social optimum point of view, we then introduce pricing, called non-cooperative feedback-rate control game with price~(NFCP). The game utility is defined as the performance gain by CSI feedback minus the price as a linear function of the CSI feedback rate. The existence of the Nash equilibrium of such games is investigated. Simulation results show that by adjusting the pricing factor, the distributed NFCP game results in close optimal performance compared with that of the centralized scheme.

TA8b1-16
Self-Optimized MIMO-OFDMA: A Nash-Stackelberg Game-Theoretic Approach
Jie Ren, Jianjun Hou, Beijing Jiaotong University; Kai-Kit Wong, University College London

This paper studies self-optimization of resource allocation for multipoint-to-multipoint orthogonal frequency-division multiple-access (OFDMA) interference channels with multiple-input multiple-output (MIMO) user terminals. Each user intends to maximize its achievable rate based on its local observation on the channels and its prediction on how other users would respond. We achieve this by constructing a Nash-Stackelberg (N-S) game in which the Nash part deals with the competition over spatial subchannels of MIMO whereas the Stacklelberg part manages the competition over frequency subcarriers among users. Simulation results demonstrate that an all-Nash game fails to reconcile users' competition and has flat user rates as a function of signal-to-noise ratio (SNR) but the proposed N-S game can achieve an order of magnitude gain in user rates which also grow with the SNR.

Track B. MIMO Communications and Signal Processing
Session: TAb8 – Cooperative and Cognitive Transmission in Multi-Antenna Systems 10:15 AM – 12:00 PM
Chair: ***Daniel Bliss,*** *MIT Lincoln Laboratory*

TA8b2-1
Cooperative Rate Maximization Based on Base Station Exchange of Powers
Samer Bazzi, Guido Dietl, DoCoMo Communications Laboratories Europe GmbH

A new iterative method for maximizing the rate of cell-edge users based on base station cooperation is proposed, where the total rate of edge users is maximized at each iteration. A two-cell multiple-input single-output (MISO) scenario with single user cells is considered, where the base stations alternately exchange power information in order to maximize a lower bound on the total sum rate. Numerical results show performance improvements for medium and high signal-to-noise (SNR) ratios over existing methods

TA8b2-2
Half-Duplex Gaussian Diamond Relay Channel with Interference Known at One Relay
Kagan Bakanoglu, Elza Erkip, Polytechnic Institute of New York University; Osvaldo Simeone, New Jersey Institute of Technology

A diamond relay channel in the presence of interference which is non-causally available only at one relay is considered. The interference signal may have structure, for example it could come from another source communicating with its own destination. However, the external interferer is not willing to adjust its communication strategy to minimize the interference and is considered to be fixed. Two approaches are possible to mitigate the interference: exploiting the structure or treating it as unstructured. Using these approaches, bounds for the Gaussian half-duplex diamond relay channel based on two transmission time patterns are established. The importance of exploiting the interference structure and transmission time patterns are discussed.

TA8b2-3
Interference Management in Femtocell Networks with Hybrid-ARQ and Interference Cancellation
Tania Villa, Eurecom; Ruben Merz, Deutsche Telekom Laboratories; Raymond Knopp, Eurecom

Femtocells are small cellular base stations targeting in-home usage and deployed by end-users. Because of the unplanned nature of their deployment, they can suffer from severe inter-cell interference with neighboring femtocells in dense deployments. In addition, coordination is hardly feasible due delays induced by the backhaul infrastructure of these home femtocell networks. We propose a novel and decentralized interference mitigation scheme that combines HARQ and incremental redundancy with an interference cancellation decoder. Our performance evaluation based on analytical modeling and Monte Carlo experiments shows that our scheme is effective at combating interference without requiring any coordination.

TA8b2-4
Achievable Degrees of Freedom of the K-User Interference Channel with Partial Cooperation
Ahmed Naguib, Khaled Elsayed, Cairo University; Mohammed Nafie, Nile University

In this paper, we consider the K-user interference channel with partial cooperation, where a strict subset of the K users cooperate. For the K-user interference channel with cooperating subsets of length , the outer bound of the total degrees of freedom is KM/(M+1). In this paper, we propose a signal space-based interference alignment scheme that proves the achievability of these degrees of freedom for the case K=M+2. The proposed scheme consists of a design for the transmit precoding matrices and a processing algorithm which we call the Successive Interference Alignment (SIA) algorithm. The decoder of each message uses the SIA algorithm to process the signals received by the M cooperating receivers in order to get the maximum available degrees of freedom.

TA8b2-5
Multicell Downlink Weighted Sum-Rate Maximization: A Distributed Approach
Pradeep Chathuranga Weeraddana, Marian Codreanu, Satya Joshi, Matti Latva-aho, Centre for Wireless Communications

We consider the problem of weighted sum-rate maximization in a multicell downlink system. The problem is NPhard and therefore difficult to solve, even in a centralized manner. We derive a distributed algorithm based on primal decomposition and subgradient methods. The key idea is to solve a sequence of successive convex approximations of the original problem in a distributed manner. By fixing the maximum interference levels created by a base station on the users located in its neighboring cells, each convex approximation is decomposed into several subproblems, one for each base station. These maximum interference levels are referred to as interference commitments and they represent the complicating (or coupling) variables. For fixed interference commitments, each base station optimizes locally its own decision variables (i.e., beamformers' directions and power allocation) by using an iterative ascent algorithm for fixed number of iterations. The interference commitments are updated by using a subgradient method when the per base station optimizations are finished. Base station optimizations and the subgradient method are carried out in an iterative fashion. Even though the global optimality of the solution cannot be guaranteed due to the nonconvexity of the original problem, the numerical results show that significant gains can be achieved by only a small amount of message passing between the cooperating base stations.

TA8b2-6
Decentralized Multi-Cell Beamforming Coordination for Multiuser MISO Systems
Harri Pennanen, Antti Tölli, Matti Latva-aho, University of Oulu

In this paper, we consider a coordinated downlink minimum power beamforming problem for a multi-cell network where each multiantenna base station (BS) serves multiple single antenna users. We propose an iterative beamforming algorithm using a primal decomposition method. It turns the original centralized optimization into a decentralized two level optimization requiring limited backhaul signaling between coordinated BSs. At the lower optimization level, local beamformers are solved with the aid of uplink-downlink duality. Hence, convex optimization tools are not needed in the beamformer design. Due to the convexity of the original problem the proposed approach converge to the globally optimal solution. Unlike most of the previous approaches the proposed method guarantees feasible beamformers at each iteration.

TA8b2-7
Feedback Reduction by Thresholding in Multi-User Broadcast Channels: Design and Limits
Matthew Pugh, Bhaskar D. Rao, University of California, San Diego

To utilize the multi-user diversity in broadcast channels, the channel state information (CSI) of each user must be known at the transmitter. To reduce the overhead of CSI feedback under random beamforming the question of which receivers should feed back their CSI is investigated. Using the closed form expression for the SINR distribution, thresholding functions $T(n)$ are designed to meet specific design criterion as a function of the number of receivers. Specifically three design criterion are proposed. The asymptotic limits of the successful thresholding functions $T(n)$ are found. If $T(n)$ scales slower than $\log n$, asymptotically no performance is lost. If $T(n)$ scales faster than $\log n$, all multi-user diversity is lost.

TA8b2-8
Full-Duplex Bidirectional MIMO: Achievable Rates under Limited Dynamic Range
Brian Day, Ohio State University; Daniel Bliss, Adam Margetts, MIT Lincoln Laboratory; Philip Schniter, Ohio State University

In this paper we consider the problem of full-duplex bidirectional communication between a pair of modems, each with multiple transmit and receive antennas. The principal difficulty in implementing such a system is that, due to the close proximity of each modem's transmit antennas to its receive antennas, each modem's outgoing signal can exceed the dynamic range of its input circuitry, making it difficult---if not impossible---to recover the desired incoming signal. To address these challenges, we consider systems that use pilot-aided channel estimates to perform transmit beamforming, receive beamforming, and interference cancellation. Modeling transmitter/receiver dynamic-range limitations explicitly, we derive tight upper and lower bounds on the achievable sum-rate, and propose a transmission scheme based on maximization of the lower bound, which requires us to (numerically) solve a nonconvex optimization problem. In addition, we derive an analytic approximation to the optimized sum-rate, and show, numerically, that the approximation is quite accurate.

Track D. Signal Processing and Adaptive Systems
Session: TAb8 – Adaptive Sensing 10:15 AM – 12:00 PM
Chair: ***Jarvis Haupt,*** *University of Minnesota*

TA8b3-1
Adaptive Search for Sparse Moving Targets under Resource Constraints
Gregory Newstadt, Eran Bashan, Alfred O. Hero, University of Michigan

Previous work with adaptive search for sparse static targets under resource constraints has produced two-stage allocation policies with desirable properties for asymptotic SNR. This work investigates the problem of extending the allocation policies to T >> 2 stages, with particular emphasis on cases where the SNR for any particular stage is considerably less than the asymptotic level. This work provides a new formulation that can account for non-static targets, including a transition model for target locations and a population mode. Under this formulation, a dynamic adaptive resource allocation policy (D-ARAP) is proposed. It is shown through Monte Carlo simulation that this policy provides significant gains over an exhaustive search in both static and dynamic target cases. Moreover, the comparison is made to the optimal solution of partially observable Markov decision processes.

TA8b3-2
Adaptive Signal Recovery in Noisy Environments
Mark Iwen, Duke University; Ahmed H. Tewfik, The University of Texas at Austin

We study the problem of recovering a signal with a sparse representation in a given orthonormal basis using as few noisy observations as possible. As opposed to previous studies which consider additive measurement noise that is independent of the measurement process, this paper considers observations which are subject to the type of 'clutter noise' encountered in radar applications (i.e., the utilized measurements influence the observed noise). Given this model, the paper develops bounds on the number of adaptive measurements required to reconstruct the support of the signal when the measurement noise is uncorrelated with bounded variance and fixed mean. This paper generalizes previous results concerning i.i.d. Gaussian background noise.

TA8b3-3
On the Limits of Sequential Testing in High Dimensions
Matthew Malloy, Robert Nowak, University of Wisconsin

This paper presents results pertaining to sequential methods for support recovery of sparse signals in noise. Specifically, we show that any sequential measurement procedure fails provided the average number of measurements per dimension grows less then log s /D(f_0||f_1) where s is the level of sparsity, and D(f_0||f_1) the Kullback-Leibler divergence between the underlying distributions. Moreover, we show that a simple procedure termed sequential thresholding guarantees exact support recovery provided the average number of measurements per dimension grows faster than 2 log s /D(f_0||f_1), a mere factor of 2 more than the lower bound. Lastly, we show any non-sequential procedure fails provided the number of measurements grows at a rate less than log n /D(f_1||f_0), where n is the total dimension of the problem.

TA8b3-4
Active Learning for Adaptive Life-Long Learning
Lawrence Carin, Duke University; Hui Li, Signal Innovations Group

There has been significant recent interest in active for classifier design, in which one seeks to define unlabeled data for which labels are to be acquired, based upon such measures as mutual information. Almost all of that previous work has been done in a single-task-learning setting, which implies that each sensing problem is treated anew, as if sensing had never been done before. It is more desirable for the algorithm to engage in "life-long" learning, in which appropriate experiences (data) from previous sensing missions are transferred to the current sensing task. We consider this problem, in which a transfer-learning-based semi-supervised classifier is designed, with the Dirichlet process employed to infer relationships between sensing tasks encountered over the sensor "lifetime". Further, active learning is applied sequentially over time, as new sensing tasks are encountered. When there is significant experience from the past that may be leveraged, the amount of new active learning is minimal, while when the algorithm infers that the data at a given sensing mission are different from those encountered previously, the quantity of active learning that occurs increases. This framework is demonstrated on real underwater acoustic sensing data.

TA8b3-5
Efficient Adaptive Compressive Sensing Using Sparse Hierarchical Learned Dictionaries
Akshay Soni, Jarvis Haupt, University of Minnesota

Recent breakthrough results in compressive sensing (CS) have established that many high dimensional objects can be accurately recovered from a relatively small number of non-adaptive linear projection observations, provided that the objects possess a sparse representation in some basis. Subsequent efforts have shown that the performance of CS can be improved by employing either an assumption of structure in the location of the nonzero signal coefficients (structured sparsity), or some form of data-dependent measurement focusing (adaptivity) in the sensing process. In this paper we examine a powerful hybrid of these two techniques. First, we describe a simple adaptive sensing procedure that is a provably effective method for acquiring sparse signals that exhibit structured sparsity characterized by low-degree graph-based coefficient dependencies. Next, employing techniques from sparse hierarchical dictionary learning, we show that representations exhibiting the appropriate form of structured sparsity can be learned from collections of training data. The combination of these techniques results in a provably effective and efficient adaptive compressive acquisition procedure.

TA8b3-6
Information-Optimal Adaptive Compressive Imaging
Amit Ashok, Mark Neifeld, University of Arizona

We adopt a sequential Bayesian experiment design framework for compressive imaging wherein the measurement basis is data dependent and therefore adaptive. The criteria for measurement basis design employs the task-specific information (TSI) metric that is conditioned on the past measurements. A Gaussian scale mixture prior model is used to represent compressible natural scenes in the wavelet domain. The resulting adaptive compressive imager design yields significant performance improvements compared to a static compressive imager whose measurement basis remains fixed during the measurement process.

TA8b3-7
On Primary Side Information in Cognitive Radio Networks
May Moussa, Mohammed Nafie, Nile University; Hesham El-Gamal, Ohio State University; Ayman Naguib, Qualcomm Incorporated

In this paper, we study the impact of the knowledge of primary side information on the efficiency of spectrum sensing for cognitive radio networks. In particular, assuming that the secondary transmitter knows the modulation and/or coding scheme used in the primary transmissions, we evaluate the efficiency of spectrum sensing in terms of maximizing the overall achievable throughput of the system. We present the results for both block-based and sequential detection techniques. We show that in sequential detection, and when the cognitive transmitter has knowledge of the primary codebook, the detection threshold should be adaptive based on the previous observations. Our results show the gains achieved over energy based techniques.

TA8b3-8
Further Results on Adaptive Sequential Detection with One-Sided Stopping and Deadline
Wenyi Zhang, University of Science and Technology of China; Ahmed Sadek, Stephen Shellhammer, Cong Shen, Qualcomm Incorporated

In many detection problems, it is desirable to respond to the alternative hypothesis (e.g., an emergent event) as soon as possible, while staying latent under the null hypothesis. Based upon this consideration, an adaptive detection scheme has been proposed recently and analyzed for a specific spectrum sensing application. In this work, further results are established for the adaptive detection scheme. A general analysis is presented and specifically asymptotic behaviors are examined in details, regarding the key performance metrics including detection powers and expected exit time. A comparative study with respect to the sequential probability ratio test (SPRT) is also provided.

Track B. MIMO Communications and Signal Processing
Session: TPa1 – Resource Allocation in Multi-Antenna Systems
Chair: ***Neelesh Mehta,*** *Indian Institute of Science*

TP1a-1 1:30 PM
Optimal Power Allocation for Multi-User Transmit Beamforming via Regularized Channel Inversion
Rusdha Muharar, Jamie Evans, University of Melbourne

In this paper, we consider an optimal power allocation problem that maximizes the sum-rate of a single-cell MISO broadcast channel with regularized channel inversion (RCI) beamforming at the base station (BS). Unlike the channel inversion or zero forcing beamforming, the optimal power allocation with RCI precoding at the base station is a nonlinear non-convex optimization problem with many local optima. Here, we investigate this problem in the large system limit, i.e., when the number of users K and antennas at the base station N tend to infinity with their ratio $\beta=K/N$ being held constant. We assume each user has data symbol with power p_k, and slow-varying path-loss a_k. Following some results in our previous works, we can obtain the expression for the signal to interference plus noise ratio (SINR) in the large system limit. Then, we divide all K users into a finite L groups where all users in each group are assumed to be co-located or to have approximately the same distance from the BS. In other words, all users in one group have the same path-loss which is distance dependent. Based on this system model, we investigate optimal power allocation schemes that maximize the sum-rate per antenna, firstly under average power constraint, and then under both average and per-group power constraints. We show that both problems are convex and the power allocation mainly follows the well-known water-filling strategy. Moreover, we also study a joint optimal power allocation and regularization parameter of RCI beamformer.

TP1a-2 **1:55 PM**

Capacity Density Optimization by Fractional Frequency Partitioning

Martin Taranetz, Josep Colom Ikuno, Markus Rupp, Vienna University of Technology

This paper presents a fractional frequency reuse optimization scheme based on capacity density. It assigns a given user to the frequency subband with maximum achievable capacity density (bit/s/m²). We formulate the optimization problem and solve it by simulation. Unlike in previous work, the problem is solved assuming interference limitation in all subbands. A sectorized layout with three-dimensional antenna radiation patterns is utilized, which includes the effect of antenna downtilting on the signal-to-interference-plus-noise ratio distribution. The simulation results show that the proposed scheme outperforms conventional Reuse-1- and Reuse-3 schemes in terms of average- and cell-edge performance.

TP1a-3 **2:20 PM**

Resource Allocation in MIMO Multi-Cellular Networks via Submodular Optimization

Narayan Prasad, Honghai Zhang, NEC Laboratories America, Inc.; Luca Venturino, University of Cassino; Jubin Jose, The University of Texas at Austin; Sampath Rangarajan, NEC Laboratories America, Inc.

In this paper we consider coordinated resource allocation among multiple cells in a cellular downlink. We formulate several such coordinated resource allocation problems as mixed optimization problems, all of which account for practical constraints that will be ubiquitous in the emerging fourth generation cellular networks. We prove that the formulated problems are NP hard. We then proceed to show that many of these problems are equivalent to sub-modular optimization problems under (multiple) matroid constraints and propose low complexity approximation algorithms yielding worst-case performance guarantees.

TP1a-4 **2:45 PM**

Transmit Power Optimization for Multi-Antenna Decode-and-Forward Relays with Loopback Self-Interference from Full-Duplex Operation

Taneli Riihonen, Stefan Werner, Risto Wichman, Aalto University

We develop transmit power control schemes for a full-duplex decode-and-forward relay link. As a new aspect for the optimization problem, we note that the practical implementations of full-duplex relays are subject to unavoidable self-interference propagating from the transmit antenna array to the receive antenna array. In particular, multiantenna techniques facilitate performance improvement by directing interference power to the least harmful spatial dimensions. As a result of transmit power optimization, the end-to-end transmission rate is maximized while, at the same time, the relay transmit power is decreased. Finally, we compare full-duplex relaying to half-duplex relaying: We illustrate the benefit of choosing one over the other and evaluate the conditions where each is preferred.

Track A. Communications Systems

Session: TPb1 – Interference Management

Chair: ***Aydin Sezgin,*** *University of Ulm*

TP1b-1 **3:30 PM**

Degrees of Freedom of Multiple Unicasts over Multihop Wireless Networks

Syed Jafar, University of California, Irvine

Recent results on degrees of freedom characterization for multiple unicasts over multihop wireless networks are presented. In particular, the role of a new technique, called aligned interference neutralization, is highlighted in a variety of settings.

TP1b-2 **3:55 PM**

Optimized Data Symbol Sharing in Multiple-Antenna Interference Channel

Maha Odeh, Paul De Kerret, David Gesbert, Eurecom

Multicell cooperative transmission is a promising tool to tackle interference and hence elevate the spectral efficiency of future wireless systems. However, such techniques present a substantial burden on the infrastructure as they require full sharing of the user data across all cooperating transmitters. On the other hand, interference can be tackled more locally when multiple antennas are available at some base station. In this paper we demonstrate that when the total number of antennas located at the transmitters in the whole network exceeds the number of users to be served one can efficiently reduce the downlink data information sharing overhead by properly routing each data symbols to a limited and appropriate set of base stations while at the same maintaining the interference cancellation over the network. This paper first presents optimal and suboptimal routing solutions(i.e. exhibiting minimum symbol sharing) that guarantees the maximum number of degrees of freedom (multiplexing gain). Then we exhibit a trade-off between symbol sharing overhead and the achievable data rates obtained with multicell MIMO precoding at finite SNR.

TP1b-3 **4:20 PM**

On Interference Channels with more than Two Source-Destination Pairs

Daniela Tuninetti, University of Illinois, Chicago

Recently much progress has been made toward understanding the ultimate performance of interference networks; in particular, the capacity region of the Gaussian channel with two source-destination pairs has been characterized to within one bit. Much less is known about non-Gaussian channels or for channels with more then two source-destination pairs. This paper proposes an outer bound for a general memoryless interference channel with an arbitrary number of source-destination pairs. In Gaussian noise, we identify a class of channels for which the proposed outer bound gives the sum-rate capacity; this class contains both the generalization of the two-user degraded channel and of the two-user Z-channel.

TP1b-4 **4:45 PM**

Training and Feedback Optimization For MIMO Interference Alignment in Continuous Fading Channels

Omar El Ayach, Angel Lozano, Universitat Pompeu Fabra; Robert W. Heath, Jr., The University of Texas at Austin

In this paper we study the performance of interference alignment in continuously fading multiple input multiple output channels where channel knowledge is achieved by training and analog feedback. We derive optimal training and feedback resource allocations accounting for estimation error, feedback overhead, and channel selectivity. We analyze the effective sum-rate with overhead in relation to various system operating parameters such as signal-to-noise ratio and doppler spread.

TP1b-5 **5:10 PM**

Making Optimal Use of the Asymmetric Interference Channel

Rachel Learned, MIT Lincoln Laboratory

The asymmetric interference channel is an appro- priate model for many realistic scenarios, especially those arising more frequently as dynamic spectrum access (DSA) becomes more prevalent. As DSA nodes evolve to become more cognitive, e.g. self aware, environment aware, and adaptive, the prevailing white space seeking and gray space adapting policies leave a significant portion of the spectrum, namely, the black space, untapped. This paper offers a throughput versus SINR result and corresponding technique for jointly choosing the transmission rate and multiuser detection algorithm that allows computationally constrained cognitive DSA nodes high rate oper- ation in spectrum black space. In addition, this paper derives an information theoretic motivated policy for seemingly insignificant waveform design choices that greatly enhance the throughput of a secondary sender-receiver pair while fulfilling a given complexity requirement within the secondary node's receiver. This paper shows typical throughput improvements of 10 to 50 times when using this technique over the traditional approach to maintaining a disadvantaged link within an asymmetric interference channel.

Track A. Communications Systems

Session: TPa2 – Cognitive Radio I

Chair: ***Osvaldo Simeone,*** *New Jersey Institute of Technology*

TP2a-1 **1:30 PM**

Joint Link Learning and Cognitive Radio Network Sensing

Seung-Jun Kim, Georgios B. Giannakis, University of Minnesota

Cognitive radios (CRs) sense the RF environment to detect underutilized spectral resources in the frequency, time, and space domains, so that they can transmit without disrupting primary user (PU) systems that hold the license of the operating bands. Sensing performance thus critically influences the overall CR system. A major challenge of the sensing task is due to the lack of prior information on the PU signal characteristics, and/or the absence of explicit support of channel estimation from the PU system. While the difficulties can be ameliorated by allowing collaboration among a network of CRs, joint blind channel learning can further improve the overall system performance. In this work, novel techniques are developed for joint link learning and PU detection by leveraging recent advances on compressive sampling methods, and their performance is analyzed through numerical tests.

TP2a-2 **1:55 PM**

Spectrum Sensing via Event-Triggered Sampling

Yasin Yilmaz, Xiaodong Wang, Columbia University

We consider cooperative sequential spectrum sensing for cognitive radio (CR) networks under bandwith constraints. Novel sequential spectrum sensing schemes that use asynchronous and quantized communication between nodes and the central unit are proposed. Our proposed algorithms outperform a suboptimal soft combination (data fusion) technique by using a much cheaper hard combination (decision fusion) technique. We also introduce intuitive and easy to follow proofs for asymptotic optimality properties of the proposed algorithms. In discrete-time, our scheme, by using at most 3 bits, attains 2nd order asymptotic optimality and a decision delay performance very close to the optimal performance of the centralized SPRT (Sequential Probability Ratio Test) scheme in a practical case where error probabilities vary between 10□1 and 10□4. Restricting ourselves to 1-bit communication, we achieve an improved 1st order (almost 2nd order - 2nd order in practical cases) asymptotic optimality and a significantly better detection delay performance than D-SPRT of [1] and [2], which is asymptotically optimal of order 1 in discrete-time. In continuous-time or in discrete-time with sufficiently small timesteps, all our algorithms are asymptotically optimal of order 2. The proposed algorithms in this paper and D-SPRT are shown to be utilizing MMSE (Minimum Mean Square Error) estimation for unknown samples at the central unit. We explain the Lebesgue sampling and quantization natures of our schemes. Finally, we demonstrate the asymptotic and time-progress performances of our proposed algorithms by comparing them to the optimum centralized SPRT scheme and the uniformly sampled non-quantized centralized SPRT scheme.

TP2a-3 **2:20 PM**

Proactive Resource Allocation in Cognitive Networks

John Tadrous, Atilla Eryilmaz, Hesham El-Gamal, Ohio State University

We consider proactive resource allocation for wireless networks in the presence of two classes of users with different Quality-of-Service (QoS) requirements, and with predictable service demand characteristics. The first is a primary class that is assumed to have the priority to access the network, whereas the other is a secondary class with cognitive radio capabilities that opportunistically accesses the network resources to improve its utilization. Assuming that the cognitive radio requests are unpredictable, we analyze the diversity gain performance of both classes when the primary requests are non-predictable and when they are predictable. We show that, under selfish behavior of the predictive primary network, the outage probability, measured by the associated diversity gain, of the secondary network cannot be improved over its non-predictive counterpart. This motivates us to introduce another ``less-selfish'' scheduling policy for the primary network which maintains the same diversity gain for the primary and, at the same time, improves the diversity gain of the secondary user, which is called \emph{the good citizen behavior}. We also provide numerical simulations to support the analytical results.

TP2a-4 **2:45 PM**

Correlated Equilibrium Learning Algorithms for Dynamic Spectrum Access

Jane Wei Huang, Vikram Krishnamurthy, University of British Columbia

We propose a novel adaptive regret based learning procedure which tracks the set of correlated equilibria of a slowly time-varying game. The learning algorithm is novel in that it allows agents to share information with other agents in its local vicinity and does not require any information from agents outside this vicinity. We illustrate the use of this algorithm in dynamic spectrum access among cognitive radios from an adaptive, game theoretic learning perspective. Spectrum-agile cognitive radios compete for channels temporarily vacated by licensed primary users in order to satisfy their own demands and minimize interference.

Track A. Communications Systems

Session: TPb2 – Cognitive Radio II

Chair: ***Osvaldo Simeone,*** *New Jersey Institute of Technology*

TP2b-1 **3:30 PM**

Extreme Eigenvalue Distributions of Finite Random Wishart Matrices with Application to Spectrum Sensing

Giuseppe Abreu, University of Oulu; Wensheng Zhang, Mamiko Inamori, Yukitoshi Sanada, Keio University

We employ a unified framework to express the exact cumulative distribution functions (CDF's) and probability density functions (PDF's) of both the largest and smallest eigenvalues of central uncorrelated complex random Wishart matrices of arbitrary (finite) size. The resulting extreme eigenvalue distribu- tions, which are put in simple closed-forms, are then applied to build a Hypothesis-Test to solve the Primary User (PU) detection problem (aka Spectrum Sensing), relevant to Cognitive Radio (CR) applications. The proposed scheme is shown to outperform all asymptotic approaches recently proposed, as consequence of the fact that the distributions of the extreme eigenvalues are closed-form and exact, for any given matrix size.

TP2b-2 **3:55 PM**

Autocorrelation-Based Multi-Antenna Spectrum Sensing in Colored Noise

Jitendra Tugnait, Auburn University

One of the first steps to be accomplished by a cognitive user in cognitive radio applications is spectrum sensing: analysis of the received electromagnetic transmissions to search for unoccupied spectrum bands (spectrum holes). Recently several time-domain approaches relying on the generalized likelihood ratio test (GLRT) paradigm have been proposed for multiple antenna spectrum sensing in cognitive radios. These approaches are suitable for flat-fading channels in white noise with equal noise variances across antennas; knowledge of the noise variance is not required, unlike the energy detector. In this paper we investigate a method based on the sample autocorrelation of the received multiantenna signal where we allow the noise to be colored and its variances to be different at different antennas without requiring knowledge of their spectra. Supporting simulation examples are provided.

TP2b-3 **4:20 PM**

Decentralized Cognition via Randomized Masking

Kamyar Moshksar, Amir Khandani, University of Waterloo

A decentralized network of one Primary User (PU) and several Secondary Users (SU) is studied. The number of SUs is modeled by a random variable with a globally known distribution. PU is licensed to exploit the resources, while the party of SUs intend to share the resources with PU. Each SU must guarantee to not disturb the performance of PU beyond a certain level, while maintaining a satisfactory quality of service for itself. It is proposed that each secondary transmitter adopts a Randomized Masking (RM) strategy where it remains silent or transmits a symbol in its codeword independently from transmission slot to transmission slot. We consider a setup where the primary transmitter is unaware of the channel gains, the code-book of the secondary users and the number of secondary users. Although the SUs are anonymous to each other, i.e, they are unaware of each other's code-book, each SU is smart in the sense that it is aware of the code-book of PU, the channel gains and the number of active SUs. Invoking the concept of epsilon-outage capacity, we define the epsilon-admissible region as the set of possible transmission rates for PU and possible masking probabilities for each SU such that the probability of outage for PU is maintained under a threshold epsilon. Thereafter, the transmission rate of PU and the masking probability of SUs are designed by maximizing a globally known utility function of the rates of users over the "-admissible region. In our analysis, the primary receiver treats interference as noise, however, each secondary receiver has the option to decode interference caused by PU, while treating the signals of other SUs as noise. In another scenario, referred to as Power Allocation (PA), each SU transmits continuously (no masking is applied), however, it regulates its transmission power yielding the largest utility value. It is demonstrated that the PA scheme is more appropriate in the regime that the transmission power of PU is relatively low, while the RM scheme outperforms PA for comparably larger values of the transmission power of PU.

TP2b-4 **4:45 PM**

Spectrum Leasing via Cooperative Opportunistic Routing in Distributed Ad Hoc Networks: Optimal and Heuristic Policies

Cristiano Tapparello, Davide Chiarotto, Michele Rossi, University of Padova; Osvaldo Simeone, New Jersey Institute of Technology; Michele Zorzi, University of Padova

A spectrum leasing strategy is considered for the coexistence of a licensed multihop network and a set of unlicensed nodes. Secondary nodes can be used by the primary network as extra relays and hence potential next hops following the principle of opportunistic routing. Secondary cooperation is guaranteed via the spectrum leasing via cooperation mechanism, whereby a cooperating node is granted spectral resources subject to a QoS constraint. The objective of this work is to find optimal as well as efficient heuristic routing policies based on the idea outlined above. The optimal policy is obtained by casting the problem in the framework of stochastic routing. The optimal performance is then numerically compared with two proposed heuristic routing schemes, which are shown to perform close to optimal solutions and as well being tunable in terms of end-to-end throughput vs primary energy consumption.

TP2b-5 **5:10 PM**

A Message-Passing Algorithm for Spectrum Access in Cognitive Radio Relay Networks

Sang Hyun Lee, Manohar Shamaiah, Sriram Vishwanath, Haris Vikalo, The University of Texas at Austin

This work addresses the spectrum access problem in cognitive radio relay networks. In our setup, primary users allow secondary users access to the channel (spectrum) as long as they agree to relay primary users' data in addition to their own. We desire to maximize the network usage by determining the best configuration of matching between primary users and secondary users. This problem can be formulated in a form similar to maximum weighted matching. Given this formulation, we develop an algorithm for this problem using affinity propagation that is fully distributed. We test its performance and demonstrate convergence.

Track D. Signal Processing and Adaptive Systems

Session: TPa3 – Multi-dimensional Compressive Inference

Chair: ***Phil Schniter,*** *The Ohio State University*

TP3a-1 **1:30 PM**

Real-Time Principal Component Pursuit

Graeme Pope, Manuel Baumann, ETH Zurich; Christoph Studer, Rice University; Giuseppe Durisi, Chalmers University of Technology

Robust PCA deals with the decomposition of a matrix into a low-rank and a sparse matrix, which has uses in video surveillance and face recognition. Many algorithms to solve this problem have prohibitive computational complexity. We propose a variety of methods that significantly reduce the computational complexity and perform an analysis of these techniques. For synthetic data we demonstrate a speedup of more than 365 times compared to a base C implementation at a small penalty in terms of reconstruction error. To demonstrate the effectiveness of our approach, we consider foreground/background separation for video surveillance, where our methods enable real-time processing of a 640x480 color video stream at 10 fps using an off-the-shelf PC.

TP3a-2 **1:55 PM**

Low Rank Variational Tensor Recovery for Multi-Linear Inverse Problems

Hatim Alqadah, H. Howard Fan, University of Cincinnati

In this work we consider the tensor recovery problem with a sparsity constraint on the variation along one or more of the tensor dimensions. We approach the problem by formulating a convex problem in which the n-rank of the tensor variation is used as a sparsity measure. This approach has applications in the sparse regularization of multi-dimensional inverse problems. The de-noising of 3D MRI data was used as a proof of concept of our approach.

TP3a-3 **2:20 PM**

Optimized Measurements for Kernel Compressive Sensing

Karthikeyan Natesan Ramamurthy, Andreas Spanias, Arizona State University

Certain classes of signals can be represented using a few principal components in a feature space that are obtained by nonlinear transformations of the input signal space. Compressive sensing of such signals using random measurements can be performed using the kernel trick. We propose a method for computing optimized measurements in kernel compressive sensing. The optimized measurement vectors are the data samples that have the highest energy when projected on the kernel principal components. Results obtained with handwritten digits show that using the proposed measurements results in a substantially better recovery when compared using the same number of random measurements.

TP3a-4 **2:45 PM**

Efficient Message Passing-Based Inference in the Multiple Measurement Vector Problem

Justin Ziniel, Philip Schniter, Ohio State University

We report on the application of a recently developed message passing algorithm for solving dynamic compressive sensing (CS) problems to an important sub-class of problems commonly known as multiple measurement vector (MMV) problems. In traditional MMV problems, the objective is to recover a collection of sparse vectors that all share a common support from a collection of measurement vectors. We demonstrate that the dynamic CS algorithm is well-suited to the MMV problem, and offers both impressive performance and computational efficiency.

Track D. Signal Processing and Adaptive Systems

Session: TPb3 – Advances in Adaptive and Distributed Filtering

Chair: ***Vitor Nascimento,*** *University of Sao Paulo*

TP3b-1 **3:30 PM**

Continuous-Time Distributed Estimation

Vitor Nascimento, University of Sao Paulo; Ali H. Sayed, University of California, Los Angeles

Distributed learning and cognition algorithms have been applied recently to model self-organization in biological systems, such as bird flight formation and foraging behavior in fish schools. These are adaptive diffusion models that are able to reproduce reasonably well the complex behavior observed in nature. The models assume that each node (bird, fish) in the network is able to exchange information with its neighbors, and that through this local cooperation, the network of nodes is able to evolve towards

a common global objective. The processing performed by the nodes is entirely distributed and the global pattern of behavior follows as a result of the localized interactions. These aforementioned models are based on discrete-time diffusion estimation algorithms. Nevertheless, most physical phenomena exhibit continuous-time (CT) dynamics. It is therefore important to develop continuous-time counterparts of the diffusion adaptation schemes; such schemes can provide better models for complex systems with large variations in time constants. Stand-alone continuous-time adaptive schemes have been studied before in the context of control systems and numerical methods. We derive a stochastic gradient diffusion method and prove its convergence, under certain conditions on the system inputs.

TP3b-2 **3:55 PM**

Sequential Likelihood Consensus and Application to Distributed Particle Filtering with Reduced Communications and Latency

Ondrej Sluciak, Ondrej Hlinka, Markus Rupp, Franz Hlawatsch, Vienna University of Technology; Petar Djuric, Stony Brook University

We propose a distributed method for sequential computation of the joint (all-sensors) likelihood function (JLF) in a wireless sensor network. A modified consensus algorithm is used for a decentralized calculation of a sufficient statistic that describes an approximation to the JLF. Using this likelihood consensus method, the approximate JLF, reflecting the measurements of all sensors, is obtained at each sensor. Extending our previous work, we introduce a prediction step in the consensus algorithm, thus allowing on-the-fly sequential updates of the JLF using the most recent measurements. We then apply this method to obtain a distributed particle filtering scheme with low communication requirements and low latency. The performance of this distributed particle filter is demonstrated on a multiple target tracking problem.

TP3b-3 **4:20 PM**

A Unifying Framework for the Analysis of Quaternion-Valued Adaptive Filters

Clive Cheong Took, Cyrus Jahanchahi, Danilo Mandic, Imperial College London

Quaternion valued adaptive filters have been recently introduced for the processing of three- and four-dimensional signals coming from vector sensors (ultrasonic anemometers, inertial bodysensors). The widely linear quaternion least mean square (WL-QLMS) is based on augmented quaternion statistics - it caters for both the circular and noncircular data and has been shown to provide performance advantages over its their real vector-valued counterpart. However, its rigorous convergence analysis has not been introduced as yet, as e.g. the analysis of modes of convergence includes joint diagonalisation of the covariance and four pseudocovariance matrices. In this work, we first introduce a quaternion strong uncorrelating transform (QSUT), a novel way to jointly diagonalise all the quaternion valued covariance matrices coming from the widely linear model. The result is then applied to address convergence of WL-QLMS. A comparative analysis with multichannel real valued LMS (MLMS) is also provided. These analyses are supported by illustrative examples.

TP3b-4 **4:45 PM**

Joint Conditional and Steady-State Probability Densities of Weight Deviations for Proportionate-Type LMS Algorithms

Kevin Wagner, Naval Research Laboratory; Miloš Doroslovacki, George Washington University

The joint conditional probability density function of the weight deviations given the preceding weight deviations for proportionate-type least mean square (LMS) algorithms is presented. It is assumed that the individual weight step-sizes depend only on the current weight estimates. The input signal is colored and the cases when the measurement noise is present and absent are considered. The marginal conditional probability function for weight deviations is found as well. The steady-state joint probability density function for weight deviations is the eigenfunction corresponding to the eigenvalue equal to one of the integral equation representing the probability density evolution in stationary Markov chain. The kernel of the integral equation is the derived joint conditional probability density function of the weight deviations. Several examples are given where the steady-state probability density function is found by using numerical methods. The obtained results are compared with the histograms produced by Monte Carlo experiments using the proportionate-type LMS algorithm. It is shown that the theoretical steady-state probability density functions match well with the histograms.

TP3b-5 **5:10 PM**

Fast and Superfast Computations in Structured Equalization Scenarios

Ricardo Merched, Universidade Federal do Rio de Janeiro

Matrix inversion is at the heart of every single application one can think of. This includes least-squares (LS) and minimum-mean-square-error (MMSE) equalization methods as the limelights of modern signal processing and communications. We propose a unified framework for fast and superfast computation and realization of equalizers in highly structured data transmission

scenarios. Well known estimation formulas are thus generalized to account for arbitrary first order recurrence related based models, and include channel estimation methods and scalar/block linear and decision-feedback-equalizers (DFE) equalizers. We show how the arising Bezoutians admit exact representations regardless of the underlying operator.

Track C. Networks

Session: TPa4 – Communication Management in Robot Networks

Chair: ***Michael Zavlanos,*** *Stevens Institute of Technology*

TP4a-1 1:30 PM

Co-Optimization of Communication and Motion Planning of a Robotic Operation in Fading Environments

Yuan Yan, Yasamin Mostofi, University of New Mexico

In this paper, we consider the scenario that a robot needs to maximize the amount of information it sends to a fixed station as it moves along a predefined trajectory. We consider the case where the robot operates under energy and time constraints. We then show how the robot can co-optimize its velocity, motion energy and transmission rate/power along the trajectory by using probabilistic online learning of wireless channels. Our mathematical framework and simulation results show how our proposed framework results in a considerably more efficient use of the available resources.

TP4a-2 1:55 PM

A Framework for Integrating Mobility and Routing in Mobile Communication Networks

Michael M. Zavlanos, Stevens Institute of Technology; Alejandro Ribeiro, George J. Pappas, University of Pennsylvania

Most coordinated tasks performed by teams of mobile robots require reliable communications between the members of the team. Maintaining this communication capability induces physical constraints on the trajectories, but also requires determination of communication variables like routes and transmitted powers. In this paper we propose a hybrid framework to address this problem, where continuous motion controllers based on potential fields interact with discrete optimization of the communication variables, resulting in a multi-robot network that ensures integrity of communications. Our definition of network integrity differs from existing approaches in that it is not based on the topology of the network, but on metrics that are of interest to the performance of communication between robots and possibly a fixed infrastructure. In this paper, integrity is defined as the ability of a network to support desired communication rates.

TP4a-3 2:20 PM

Multi-Robot Path Following with Visual Connectivity

Magnus Lindhé, Royal Institute of Technology; Tamas Keviczky, Delft University of Technology; Karl Henrik Johansson, Royal Institute of Technology

We consider a group of N robots moving through an obstacle field, where only robots that have a clear line of sight can communicate. When passing the obstacles, the group must coordinate its motion to remain connected. We propose using the path/velocity decomposition: Given obstacle-free paths that fulfill a higher-level goal, we propose a method to coordinate the robot motions along the paths so visual connectivity is maintained. The problem is equivalent to finding a path through an N-dimensional configuration space, avoiding unconnected configurations. We solve this problem with a rapidly exploring random tree algorithm and demonstrate by simulations how the solution time varies due to the obstacle density.

TP4a-4 2:45 PM

Communication Network Challenges for Collaborative Vehicles

Pedram Hovareshti, Chen Hua, John Baras, University of Maryland

Networked systems of autonomous moving agents have emerged in a variety of applications such as collaborative robotics, unmanned aerial/ground vehicles, mobile sensor networks and disaster relief operations. The agents utilize wireless communication for distributed computing, control and decision-making. Because of the limitations on energy supply for these systems, the design and implementation of energy efficient distributed algorithms is crucial. This paper reviews the different design aspects of networks of collaborative moving vehicles. We start by addressing the different graph structures that are necessary for modeling collaborative vehicle networks. We survey the existing methods of addressing geometric connectivity, Physical and Data Link Layer, and routing issues for networks of collaborative vehicles and show the limitations of designs that address only single layer issues. We provide a systems engineering framework for the design of such systems and present the current challenges in the design of energy efficient communication networks for collaborative vehicles.

Track C. Networks

Session: TPb4 – Distributed Storage Systems

Chair: ***Alex Dimakis,*** *University of Southern California*

TP4b-1 **3:30 PM**

Codes for Robust Scalable Distributed Video-on-Demand Systems

Sameer Pawar, Salim El Rouayheb, Hao Zhang, University of California, Berkeley; Parimal Parag, Texas A&M University; Kannan Ramchandran, University of California, Berkeley

We propose a new architecture for a robust and scalable Video-On-Demand system. A key challenge encountered when designing such systems is the ability to scale in a decentralized way to dynamically adapt to changing user demands. Our proposed architecture achieves this goal through a novel and simple coding scheme that leverages the presence of unreliable caching nodes to store coded file chunks. As the popularity of certain files increase, additional cache nodes download and store the coded chunks of these files distributively on the fly with minimal stress on the server.

TP4b-2 **3:55 PM**

Error Coding for Long-Term Archival Storage Systems

Ethan Miller, Ian Adams, Jingpei Yang, Daniel Rosenthal, Darrell Long, University of California, Santa Cruz

Protecting data in long-term archival storage is a critical challenge that must be addressed to ensure the survivial of our society's legacy to the future. Because archival storage is very cost-sensitive, error codes for it must be space-efficient. Archival storage error codes must also be power-efficient: both "normal" accesses and reconstruction should access as few devices as possible. Error codes must also adapt to the wide range of failure characteristics in archival media such as tape and disk. We are exploring different approaches to error coding in this environment, and are expanding our consideration to non-volatile memories, which have recently been proposed as a potential archival storage medium.

TP4b-3 **4:20 PM**

Theoretical Problems in Fault-Tolerant Distributed Storage

James Plank, University of Tennessee

Theoreticians and systems researchers often have diverging interests. The challenges of systems research often do not require a deft mathematical touch, while interesting theory problems are, for most practical purposes, too esoteric. This paper discusses three problems in the area of fault-tolerant distributed storage that hit the intersection. All three involve erasure codes to reconstruct data when it is lost, dealing with recovery costs, computational overhead, and the degree of fault-tolerance.

TP4b-4 **4:45 PM**

Survey of Non-MDS Erasure Codes for Distributed Storage Systems

Jay Wylie, Hewlett-Packard Labs

Erasure codes such as replication, RAID 5, and other Reed-Solomon codes, are the traditional means by which storage systems are typically made reliable. As big data systems become more prevalent, more systems are comprised of huge populations of disks, and the commodity-based architecture leads to higher disk failure rates. These storage trends motivate the move towards more fault tolerant big data storage systems. Non-MDS storage codes ought to be considered for such deployments because they offer unique update cost, recovery rate, and storage efficiency trade-offs. We survey the properties of such codes we believe matter and discuss some known constructions to illustrate interesting trade offs.

Track H. Speech, Image and Video Processing

Session: TP5 – Compressive Sensing for Radar

Chair: ***Rabinder Madan,*** *U.S. Office of Naval Research*

TP5-1 **1:30 PM**

Compressive Sensing: Snake Oil or Good Idea?

Fred Daum, Raytheon

Compressive sensing is a new and useful class of algorithms which achieves surprisingly good performance at low computational complexity for certain applications under certain conditions. We study the practical utility of CS from a system engineering perspective, including such issues as: (1) limited signal-to-noise ratio data; (2) robustness to errors in modeling the physical sensor and propagation medium and complex scattering of targets; and (3) alternative algorithms that are simpler and less risky but which provide good performance in the real World. The situation is analogous to "super-resolution" algorithms.

TP5-2 **1:55 PM**

Compressive Sensing for Synthetic Aperture Radar in Fast-Time and Slow-Time Domains

Qilian Liang, The University of Texas at Arlington

In this paper, we study compressive sensing for Synthetic Aperture Radar (SAR) imaging. Via obtaining the reflectivity kernel function based on the SAR echo and transmit chirp, we observe that the reflectivity kernel function has very few non-zero values, which means SAR signal is very sparse, and compressive sensing could be applied in fast-time domain. Further more, we observe that the SAR echoes resulted from consecutive chirps have lots of redundancy, which motivates us to further exploit the redundancy among the SAR echoes in the slow-time domain. We jointly perform compressive sensing to SAR imaging in the first-time domain as well as slow-time domain, and achieve very good performance.

TP5-3 **2:20 PM**

Comparison of Compressed Sensing, MAP, and MMOSPA Estimation for Radar Superresolution

David Crouse, Peter Willett, University of Connecticut; Lennart Svensson, Chalmers University; Yaakov Bar-Shalom, University of Connecticut

We expand upon existing the literature regarding using Minimum Mean Optimal Sub-Pattern Assignment error (MMOSPA) estimates in multitarget tracking to apply it to angular superresolution of closely-space targets, noting its advantages in comparison to Maximum a Posteriori (MAP) and Minimum Mean Squared Error (MMSE) estimation. MMOSPA estimators sacrifice target labeling, but in doing so they can (often) avoid coalescence of estimates of closely-spaced objects. A compressive sensing solution, which is a form of MAP estimation, is also considered and is solved via a brute force search, which, contrary to popular belief, is computationally feasible when the number of targets is low, having execution times on the order of tens of milliseconds for two targets on a linear array.

TP5-4 **2:45 PM**

Support Recovery in Compressive Sensing for Estimation of Direction-of-Arrival

Zhiyuan Weng, Xin Wang, Stony Brook University

To estimate the direction-of-arrival (DOA) of targets, traditional array signal processing techniques sample signals at the Nyquist rate using a linear array which has inter-element distance less than or equal to half of the wavelength to avoid angle ambiguity. When the spatial signals are sparse, which is the case in many practical applications, the emerging Compressive Sensing (CS) theory enables us to use a random array to sample the spatial signals at a much lower rate while keeping the same estimation quality. In this paper, we analyze the estimation performance with use of random array. Specifically, we analyze the CS support recovery quality when the Fourier ensemble is used in the measurement. We give the sufficient and the necessary conditions for reliable support estimation.

BREAK **3:10 PM**

TP5-5 **3:30 PM**

Explore Group Sparsity for Compressive Sensing Based MIMO Radar

Yao Yu, Athina Petropulu, Junzhou Huang, Rutgers University

By exploring the sparsity of targets in the angle-Doppler-range domain, compressive sensing (CS) has been successfully applied for target estimation in collocated MIMO radar scenarios. This paper considers the widely separated multi-input multi-output (MIMO) radar and explores the applicability of CS for target estimation. In particular, the target is viewed as a collection of closely spaced small targets. As such, the return signal exhibits group sparsity in the angle-Doppler-range domain. The paper explores group sparsity to reduce the computational cost of CS without sacrificing performance.

TP5-6 **3:55 PM**

On the Role of Waveform Diversity in MIMO Radar

Benjamin Friedlander, University of California, Santa Cruz

MIMO radar employs multiple antennas to simultaneously transmit diverse waveforms, as well as multiple antennas to receive the radar returns. This paper studies the role of waveform diversity in MIMO radar as separate and distinct from the role of the multiple transmit antennas. This is done by comparing a MIMO radar system to a conceptual phased-array radar which has the same transmit and receive antennas but uses a single waveform. It is shown that when both systems perform coherent pulse integration over a number of pulses equal to the number of transmit antennas, they have very similar performance characteristics.

TP5-7 **4:20 PM**

Non-Coherent Compressive Sensing for MIMO Radar with Widely Separated Antennas

Christian Berger, Jose' Moura, Carnegie Mellon University

Coherent processing in MIMO radar using widely separated antennas faces two obstacles, for one it needs tight phase synchronization between all transmitters and receivers, secondly it is usually based on an ideal point target assumption. In recent work we have applied compressive sensing (CS) to a distributed radar setup using noncoherent combining. This seems therefore a promising approach for MIMO radar as well, although CS also makes use of a point target model. In this work we want to apply CS to a MIMO radar setup that uses noncoherent processing. To test the validity of this approach we will use a realistic target model that consists of multiple closely spaced point reflectors.

TP5-8 **4:45 PM**

Global Methods for Compressive Sensing in MIMO Radar with Distributed Sensors

Marco Rossi, Alexander M. Haimovich, New Jersey Institute of Technology; Yonina C. Eldar, Technion-Israel Institute of Technology

We study compressive sensing methods for target localization in MIMO radar. While much attention has been given to compressive sensing of signal measurements in the time domain, this work focuses on the spatial domain. We propose a framework in which the target localization with distributed, active sensors is formulated as a non-convex optimization. By leveraging a sparse representation, we also propose an algorithm that relies on global techniques to solve the non-convex localization problem. Rather than aiming to reach a local optimal solution, the proposed algorithm characterizes the topology of multiple local solutions, in order to enhance localization accuracy and resolution in low signal-to-noise scenarios and/or in the presence of multiple or extended targets.

Track E. Array Signal Processing

Session: TPa6 – Source Localization

Chair: ***Muralidhar Rangaswamy,*** *Purdue University*

TP6a-1 **1:30 PM**

Robust Time-Based Localization for Asynchronous Networks with Clock Offsets

Yiyin Wang, Delft University of Technology; Xiaoli Ma, Georgia Institute of Technology; Geert Leus, Delft University of Technology

Localization is indispensable for the successful deployment of wireless sensor networks (WSNs). Time-based localization approaches attract a lot of interest due to their high accuracy and potentially low cost. However, time-based localization is intensively coupled with clock synchronization. Thus, the reliability of timestamps in the time-based localization becomes an important yet challenging task to deal with. In this paper, we propose a robust time-based localization approach to locate a target

node with the assistance of anchors (nodes with known positions) in an asynchronous network with clock offsets. We employ the asymmetric trip ranging (ATR) protocol to obtain time-of-arrival (TOA) measurements and facilitate clock offset cancellation. Regardless of the reliability of the timestamp report from the target node, closed-form least-squares (LS) and weighted LS estimators are derived to accurately estimate the target node position. As a result, we counter the uncertainties caused by the target node by ignoring the timestamps from this node. Furthermore, Cramer-Rao Bounds (CRBs) and simulation results corroborate the efficiency of our localization scheme.

TP6a-2 **1:55 PM**

Conditioned MDS with Heterogeneous Information

Davide Macagnano, Giuseppe Abreu, University of Oulu

We consider the simultaneous localization of multi- ple sources from distance information. An extension of the super multidimensional scaling (MDS) technique to cope with non-line of sight (NLoS) conditions is given. Simulations demonstrate the superiority the proposed conditioned MDS-based solution to the recently proposed constrained sequential quadratic programming (SQP) optimization algorithm specifically designed to solve the localization problem in NLoS conditions. An advantage of our method is that why it is shown to work with distance information only, it also allows for both distance and angle information to be processed algebraically (without iteration) and simultaneously. In addition because of the flexibility of the formulation it is shown that the conditioned MDS algorithm can be solved relying on the Nystro m approximation, reducing the computational complexity of the proposed algorithm equivalent to few matrix multiplications.

TP6a-3 **2:20 PM**

Cooperative Multihop Localization with Privacy

Golaleh Rahmatollahi, Leibniz University Hannover; Giuseppe Abreu, University of Oulu; Stefano Severi, University of Bologna

We introduce a cooperative algorithm for self and target network localization with privacy. The algorithm differs form other cooperative localization algorithms in which it does not require nodes to disclose their location or even to measure (or share) their mutual distances. This is achieved by a combination of two factors: a) a novel closed-form statistical relationship between the hop- and Euclidean-distances of distributed random Breadth Search First (BSF) paths; and b) novel multihop localization algorithms. The results, compared against conventional multihop distance collection indicate that, remarkably, the privacy offered by the proposed cooperative localization algorithm does not incur any significant sacrifice in accuracy.

TP6a-4 **2:45 PM**

Design and Performance of an Integrated Waveform-agile Multi-Modal Track-before-Detect Sensing System

Jun Jason Zhang, Arizona State University; Surendra Bhat, Pennsylvania State University; Quan Ding, University of Rhode Island; Antonia Papandreou-Suppappola, Arizona State University; Ram Narayanan, Pennsylvania State University; Steven Kay, University of Rhode Island; Muralidhar Rangaswamy, Air Force Research Laboratory

We investigate agile target tracking based on the integrated multi-modal operation of radar and electro-optical sensors in low signal-to-noise ratio (SNR) scenarios. We employ the track-before-detect algorithm with particle filtering, and design the transmit waveform to improve predicted tracking performance using statistically-dependent multi-modal measurements. Our results are demonstrated using a real experimental test bed with an arbitrary waveform generator.

Track E. Array Signal Processing

Session: TPb6 – Array Processing for Satellite Communications

Chair: ***Michael Joham,*** *Technical University Munich*

TP6b-1 **3:30 PM**

On the Capacity of Multi-Beam Joint Decoding over Composite Satellite Channels

Dimitrios Christopoulos, Symeon Chatzinotas, University of Luxembourg; Michail Matthaiou, Chalmers University of Technology; Björn Ottersten, University of Luxembourg

The throughput of current multi-beam satellite systems is limited by self interference. Interference mitigation techniques have the potential of significantly increasing the spectral efficiency for these satellite communication systems. This contribution investigates the ergodic capacity bounds for the return link of a multi-beam satellite that jointly decodes signals from all users in the service area. The proposed channel model assumes unit-rank receive correlation at the collocated satellite antennas, following the well known Kronecker model. To asses the effect of line of site propagation components, channel matrix is composed of Rician fading coefficients. Moreover, lognormal fading is incorporated to model shadowing resulting from user mobility. Hence,

a composite Rician/lognormal fading channel with fully correlated receive antennas is investigated. Upper and lower ergodic sum-rate capacity bounds are calculated analytically and verified through simulations. Finally, a low-SNR analysis gives more insight on the low-SNR regime, which is the usual operating range for satellite communication systems.

TP6b-2 3:55 PM

User Scheduling for Large Multi-Beam Satellite MIMO Systems

Matteo Berioli, Vincent Boussemart, Francesco Rossetto, German Aerospace Center (DLR)

Very large size MIMO systems (hundreds of antennas) do have practical relevance, for instance in the return link of satellite communications, where the satellite may have about 100 beams and hundreds of terminals may be present in each beam. Scheduling can become very challenging in this large-size scenario: An arbitrarily selected scheduling plan may result in users with low offered rates; on the other hand searching for the best scheduling plan is unfeasible due to the huge number of possible combinations. This work proposes a low complexity heuristic based on graph theory to find a scheduling plan that well balances the offered rates to the served users.

TP6b-3 4:20 PM

Multi-User Interference Mitigation Techniques for Broadband Multi-Beam Satellite Systems

Ilaria Thibault, Francesco Lombardo, Enzo A. Candreva, Alessandro Vanelli-Coralli, Giovanni E. Corazza, University of Bologna

This paper presents a comprehensive evaluation of multi-user interference mitigation techniques for a broadband multi-beam satellite system, adopting on board, on ground and hybrid beamforming techniques. More in detail, present multi-beam satellite systems are limited by two factors, namely the effect of inter-beam interference as well as bandwidth limitations on the feeder link. The latter can be overcome by a proper digitization and compression strategy for the feeder link, which is implemented on board, while the impact of the former one is reduced by advanced signal processing techniques, which are either performed on board, at the gateway, or in both sections. Results are presented for forward and return link, based on both analytical consideration and numerical simulations on a realistic scenario.

TP6b-4 4:45 PM

Advanced Interference Mitigation Techniques for the Forward Link of Multi-Beam Broadband Satellite Systems

Bertrand Devillers, Centre Tecnològic de Telecomunicacions de Catalunya (CTTC); Ana Pérez-Neira, Universitat Politècnica de Catalunya

The deployment of a high number of beams is a key enabler for high throughput next generation satellite communication systems, which are therefore expected to operate in an interference limited regime. This increased level of interference among users can be mitigated thanks to the introduction of advanced interference mitigation techniques. Building on the concept ground-based beamforming (GBBF), a previous work on the forward link has demonstrated the gain of considering linear precoding at the gateway in the feed signal space. In this paper, we extend this work by considering advanced precoding techniques, including the polarization dimension and realistic system assumptions.

TP6b-5 5:10 PM

Performance Evaluation of a Satellite Diversity System Employing Compact MIMO-Octahedron Antenna

Tommy Hult, Lund University; Abbas Mohammed, Blekinge Institute of Technology; Zhe Yang, Lund University

In this paper we address the potential gain of using compact MIMO antenna array configurations in conjunction with satellite diversity techniques in order to increase the capacity in satellite communication systems. For this purpose, we propose a novel compact MIMO antenna which we denote as the “MIMO-Octahedron” and compare its performance with the vector element antenna and non-diversity system. Simulation results show that the MIMO-Octahedron antenna provides superior performance to the vector element antenna and the single satellite case.

Session: TPa7 – Adaptive and Evolvable Architectures

Chair: ***Andy Tyrrell,*** *University of York, UK*

TP7a-1 **1:30 PM**

A Programmable Analog and Digital Array for Bio-Inspired Electronic Design Optimization at Nano-Scale Silicon Technology Nodes

Martin Trefzer, James Walker, Andy Tyrrell, University of York

Field programmable gate arrays (FPGAs) are widely used in applications where on-line reconfigurable signal processing is required. Speed and function density of FPGAs are increasing when shrinking transistor sizes to the nano-scale. Unfortunately, in order to reliably create electronic designs according to specification time-consuming statistical simulations become necessary due to effects of intrinsic variability. This paper describes an adaptive, evolvable architecture that allows for correction and optimisation of circuits directly in hardware using bio-inspired techniques. Like FPGAs, it provides a digital configuration layer for circuit design. Accessing additional configuration options of the underlying analogue layer enables continuous adjustment of circuit characteristics.

TP7a-2 **1:55 PM**

Evolved Defect Tolerant Structures for FPGA Architectures

Pauline Haddow, Norwegian University of Science and Technology

The challenge of production defects for integrated circuits is expected to continue to increase as feature size decreases. One approach to tolerate such production defects is to apply redundancy techniques. However, today's traditional redundancy techniques are neither area nor power efficient. In this work, an evolutionary algorithm is applied to the challenge of finding new efficient structures for redundancy and such structures are applied to an FPGA architecture to provide enhanced tolerance to production defects.

TP7a-3 **2:20 PM**

Improved Learning in an Evolvable Oscillator for In-Flight Controller Adaptation in a Flapping-Wing Micro Air Vehicle

Gallagher John, Wright State University; Michael Oppenheimer, Air Force Research Laboratory

Previous work presented the design for a an adaptive evolvable oscillator that enables online, in-flight, adaptation of multiple degree-of-freedom control in an insect-scale, flapping-wing micro air vehicle based on the Harvard RoboFly. This work will provide detailed analysis of the oscillator's efficacy along with specific improvements to the on-vehicle learning engine that significantly decreases the flight time required for the adaptive controller to overcome unexpected damage to the vehicle. The paper will conclude with discussion of the implications of this work for full control of all vehicle flight modes.

TP7a-4 **2:45 PM**

Using Discrete Fourier Transforms to Detect Operational Environments for Autonomous Non-Linear Systems

Garrison Greenwood, Portland State University

Proportional-Integrative-Derivative (PID) controllers provide effective control in linear systems. However, performance is poor in nonlinear systems unless combined with a fuzzy logic controller (FLC) that modifies the PID controller gains as needed. System behavior can adapt to operational environment changes by switching different FLCs online. But that capability requires accurate operational environment identification. Identification must be done without human intervention in autonomous systems. This paper describes how Discrete Fourier Transforms can identify operational environments in an autonomous nonlinear system. Simulation results indicate the proposed method accurately identifies the environment and switches the correct FLC online to adapt the system's behavior.

Track G. Architecture and Implementation

Session: TPb7 – Computer Arithmetic II

Chair: ***Neil Burgess,*** *ARM, Inc. USA*

TP7b-1 **3:30 PM**

The Fully-Serial Pipelined Multiplier

Andrew Shafer, Advanced Micro Devices; Lyndsi Parker, IBM; Earl Swartzlander, The University of Texas at Austin

This paper presents a new multiplier design which is fully-serial and requires only 1.5N cycles to return a product. This design has been implemented for both unsigned and two's complement number systems. This design can be pipelined so that each additional multiplication only requires N cycles.

TP7b-2 **3:55 PM**

Special-Purpose Crypto Hardware Accelerators for 45nm High-Performance Microprocessors

Sanu Mathew, Ram Krishnamurthy, Intel Corporation

Encryption algorithms such as AES, RSA, and ECC are among the most performance/power-critical workloads due to the high computational complexity of mapping modular Galois-field arithmetic and arbitrary permutations onto a general-purpose microprocessor core. Furthermore, security of these algorithms is often limited by the robustness of encryption keys. Special-purpose hardware engines to accelerate symmetric/public-key encryption and high-entropy key-generation greatly improve the energy-efficiency of high-performance microprocessor platforms executing such workloads. This talk describes a multi-protocol encryption engine targeted for on-die acceleration of AES-128/192/256 encrypt/decrypt, 64b GF multiplication, multi-mode SHA hash computation and robust key generation using an all-digital True-Random-Number-Generator (TRNG) fabricated in 45nm high-K/metal-gate CMOS technology.

TP7b-3 **4:20 PM**

Energy-Efficient Floating-Point Arithmetic for Low-Power Digital Signal Processors

Syed Z. Gilani, Nam Sung Kim, University of Wisconsin-Madison; Michael J. Schulte, Advanced Micro Devices

Low-power digital signal processors have traditionally avoided hardware support for floating-point arithmetic due to their high area and power overhead. However, many emerging applications perform a significant number of floating-point operations that can significantly benefit from floating-point hardware. In this paper, we present a novel architecture for a low cost and power-efficient floating-point single-precision fused multiply-add unit that exploits the characteristics of common DSP applications.

TP7b-4 **4:45 PM**

Testing Fused Multiply Add Implementations

David Lutz, Neil Burgess, Sabrina Romero, ARM

Floating-point validation is largely involved with finding corner cases, and fused multiply add has more corners than any other operation. We used three approaches to find potential bugs: (1) a focused random generator; (2) a tabular analysis of the possible intersections of mathematical corners, with hand-generated tests to cover each entry; and (3) an exhaustive test of a scaled-down design. This paper will give details of these three approaches and the time required to implement them, drawing some conclusions concerning the difficulty of testing this function.

TP7b-5 **5:10 PM**

Shared Implementation of Radix-10 and Radix-16 Division Algorithm with Limited Precision Primitives

Milos D. Ercegovac, University of California, Los Angeles; Robert McIlhenny, California State University, Northridge

We present a shared implementation of radix-10 and radix-16 fixed-point digit-recurrence algorithm for division operation using limited-precision multipliers, adders, and table-lookups. We discuss the proposed algorithm, its design, and its ASIC implementation using a standard cell library. We present the cost and delay characteristics for precisions of 7 (single-precision), 8, 14 (double-precision) decimal digits, and single and double precision for radix-16. The proposed scheme uses short (2-3 digit-wide) operators which leads to compact modules, reduced interconnections and has an advantage at the layout level as well as in power optimization.

Session: TPa8 – Techniques for Space-Time Signal Processing 1:30 PM – 3:10 PM

Chair: ***Kaibin Huang,*** *Yonsei University, S. Korea*

TP8a1-1
Equivalent Codes and Optimality of Orthogonal Space-Time Block Codes

Alex Geyer, Sergiy Vorobyov, Norman Beaulieu, University of Alberta

An equivalent model of a multiple-input multipleoutput communication system with orthogonal space-time block coding (OSTBC) is proposed based on the newly found connection between OSTBCs and Euclidian codes. A new asymptotic upper bound on the symbol error rate of OSTBC, which is based on distance spectra of the introduced equivalent Euclidian codes, is derived. Based on this upper bound, new general design criteria for signal constellations of OSTBCs are proposed. Some bounds relating distance properties, dimensionality, and cardinality of OSTBCs with constituent signals of equal energy are found, and a new optimal signal constellation with cardinality M = 8 for the Alamouti code is designed.

TP8a1-3
Sparse Space-Time Equalization with L1 Norm

Laura Slivinski, Brown University; Adam Margetts, Daniel Bliss, Massachusetts Institute of Technology

Space-time adaptive equalizers are an important part of multiple-input multiple-output (MIMO) communication systems operating in multi-path environments. Traditional methods of producing adaptive equalizers using short training sequence lengths suffer performance loss, and do not take advantage of known properties of the channel, such as sparsity. We discuss an iterative shrinkage algorithm which utilizes the L1 norm as a procedure to estimate a sparse equalizer. We present the results of this algorithm in simulations under multiple system models, comparisons to results found using traditional methods, and advantages of sparse methods.

TP8a1-4
Weighted Sum-Rate Maximization for MISO Downlink Cellular Networks via Branch and Bound

Satya Joshi, Pradeep Chathuranga Weeraddana, Marian Codreanu, Matti Latva-aho, Centre for Wireless Communications

The problem of weighted sum-rate maximization (WSRMax) in multicell downlink multi-input single-output (MISO) systems is considered. The problem is known to be NP-hard and it plays a central role in resource allocation, link scheduling, and in finding achievable rate regions. We propose a solution method, based on branch and bound technique, which solves globally the nonconvex WSRMax problem with an optimality certificate. Specifically, the algorithm computes a sequence of asymptotically tight upper and lower bounds and it terminates when the the difference between the upper and lower bound is smaller that a pre-specified tolerance. Novel bounding techniques via conic optimization are introduced and their efficiency is demonstrated via numerical simulations. The proposed method can be used to provide performance benchmarks by back-substituting it into many existing network design problems which relies on solving WSRMax problem (e.g., it allows to evaluate the performance loss encountered by any heuristic method for WSRMax). Finally, the method proposed here is not restricted to WSRMax; it can also be used to maximize any system performance metric that can be expressed as a Lipschitz continuous and increasing function of SINR values.

TP8a1-5
Low Complexity Generalized Geometric Mean Decomposition and DFE Transceiver Design

Chih-Hao Liu, P. P. Vaidyanathan, California Institute of Technology

The complexity of the generalized geometric mean decomposition (GGMD) depends on the GGMD parameters. This paper consider the low complexity GGMD (LCGGMD) which has the least complexity within the class of GGMD. LCGGMD can be used in designing an optimal decision feedback equalizer (DFE) transceiver for a multi-input-multi-output (MIMO) channel. A novel iterative receiver detection algorithm for the receiver is also proposed.A LCGGMD transceiver always has less or equal design and implementation complexity as compared to a GMD DFE minimum mean square error (MMSE) transceiver. For the applications in which the SVDs of the equivalent MIMO channel matrices can be easily computed, such as cyclic prefix (CP) systems, the proposed LCGGMD transceiver has the most complexity-advantage over the GMD transceiver when the size of data block is highly factorable. In the simulations, LCGGMD transceivers are designed for CP systems and performance comparisons are made with well-known transceivers.

TP8a1-6
Worst-Case Robust Multiuser Transmit Beamforming Using Semidefinite Relaxation: Duality and Implications
Tsung-Hui Chang, National Tsing Hua University; Wing-Kin Ma, Chinese University of Hong Kong; Chong-Yung Chi, National Tsing Hua University

This paper studies a downlink multiuser transmit beamforming design under spherical channel uncertainties, using a worst-case robust formulation. This robust design problem is nonconvex. Recently, a convex approximation formulation based on semidefinite relaxation (SDR) has been proposed to handle the problem. Curiously, simulation results have consistently indicated that SDR can attain the global optimum of the robust design problem. This paper intends to provide some theoretical insights into this important empirical finding. Our main result is a dual representation of the SDR formulation, which reveals an interesting linkage to a different robust design problem, and the possibility of SDR optimality.

TP8a1-7
Transmitter Optimization for MIMO Systems with Mutual Coupling at High SNR
Peng Li, Hong Kong University of Science and Technology; Liang Sun, Alcatel-Lucent Shanghai Bell; Matthew McKay, Ross Murch, Hong Kong University of Science and Technology

This paper considers the optimal transmit precoder design for MIMO systems operating with antenna mutual coupling at high signal to noise ratios (SNR). The design problem is formulated as a convex optimization problem with \emph{two} separate power constraints: a constraint on the available power imposed on a per-antenna basis, and a sum constraint on the allowable radiated power. To gain insights into the mutual coupling effect and to simplify the optimization problem, sufficient and necessary conditions on the power constraints are derived, under which the dual-constraint problem reduces to a single-constraint problem with a closed-form solution. An efficient suboptimal algorithm is also proposed for the dual constraint problem by relaxing the per-antenna power constraint to sum power constraint. One interesting conclusion of our analysis is that, with mutual coupling, isotropic inputs are not optimal in general at high SNR. Our proposed optimal precoder design is shown to yield significant improvements compared to conventional techniques which are designed based on one power constraint only.

TP8a1-8
Robust Joint Optimization of Non-Regenerative MIMO Relay Channels with Imperfect CSI
Ebrahim A. Gharavol, Erik G. Larsson, Linköping University

In this paper, we deal with the problem of joint optimization of the source precoder, the relay beamformer and the destination equalizer in a nonregenerative relay network with only a partial knowledge of the Channel State Information (CSI). We model the partial CSI using a deterministic norm bounded error model, and we use a system-wide mean square error performance measure which is constrained based on the transmit power regulations for both source and relay nodes. Most conventional designs employ the average performance optimization, however, we solve this problem from a worst-case design perspective. The original problem formulation is a semi-infinite trilinear optimization problem which is not convex. To solve this problem we extend the existing theories to deal with the constraints which are semi-infinite in different independent complex matrix variables. We show that the equivalent approximate problem is a set of linear matrix inequalities, that can be solved iteratively. Finally simulation results assess the performance of the proposed scheme.

Track E. Array Signal Processing
Session: TPa8 – Statistical and Array Signal Processing for Biomedical Applications **1:30 PM – 3:10 PM**
Chair: ***Monica Bugallo,*** *University of Stony Brook*

TP8a2-1
ECG De-Noising Using a Dynamical Model and a Marginalized Particle Filter
Chao Lin, TéSA Laboratory; Monica Bugallo, Stony Brook University; Corinne Mailhes, Jean-Yves Tourneret, University of Toulouse

The development of robust ECG denoising techniques is important for automatic diagnoses of cardiac disease. A nonlinear dynamic model was recently introduced for the generation of realistic synthetic ECG signals. This paper proposes to modify this dynamical model to further adapt to morphology variations. A marginalized particle filter is then investigated to estimate the state of the resulting modified nonlinear state-space model. Quantitative evaluations on the MIT-BIH database show that the marginalized particle filter algorithm provides better results than the usual extended Kalman filter for ECG denoising.

TP8a2-2

Beta Dirichlet Process Mixture Model Based Clustering of DNA Methylation Array Data

Jia Meng, Yufei Huang, The University of Texas at San Antonio; Lin Zhang, China University of Mining and Technology

Epigenetics including DNA methylation concern the heritable changes in gene function that cannot be explained by changes in DNA sequence. Large scale methylation arrays are now being used to study genome-wide methylation. The Illumina GoldenGate is a popular platform to study methylation at a large number of loci. Model based cluster analysis is often used to identify DNA methylation subgroups in data, but it is unclear how to cluster DNA methylation data in a scalable and reliable manner. We propose a novel beta Dirichlet Process Mixture Model based method to navigate clusters in Illumina GoldenGate Methylation data. It is an infinite mixture model ,which does not require the number of cluster given in advance. We demonstrate the advantages of our proposed method on both simulated and publicly available Illumina GoldenGate Methylation dataset.

TP8a2-3

Neonatal Seizure Detection Using Multi-Channel Blind Information Fusion

Huaying Li, Aleksandar Jeremic, McMaster Univeristy; Kenneth Tan, University of Melbourne

A seizure is defined clinically as a paroxysmal alteration in neurologic function, i.e., behavioral, motor, or autonomic function. It is a result of excessive electrical discharges of neurons, which usually develop synchronously and happen suddenly in the central nervous system (CNS). It is critical to recognize seizures in newborns, since they are usually related to other significant illnesses. Seizures are also an initial sign of neurological disease and a potential cause of brain injury. In hospitals, a physician usually orders more laboratory tests when it is difficult to use the current test results to judge if a surgical operation is \ necessary or not. Similarly, in the seizure detection problem, multiple detectors can be used in order to accurately determine if there are seizure activities in the EEG or not. These multiple detectors observe the common phenomenon, the neonatal EEG, and make decisions on their own observations. The decisions are sent to a central processor, named as the fusion center. In the fusion center, the final decision is made by combining the received decisions in some way. The phenomenon, multiple local detectors, and the fusion center are the basic components of a distributed detection system. Usually, when the local decision rules are fixed, the fusion center requires the perfect knowledge on the prior information of the phenomenon and the performances of the detectors to optimally fuse the local decisions. However, such knowledge is not always available in practical applications. Moreover the prior probabilities i.e., seizure frequency may be patient dependent. Furthermore, the anomalies (probabilities of miss and false alarm) of currently used algorithms for seizure detection in neonates may also be patient dependent and thus unknown in practice. To account for the unknown properties of local detectors in our previous work, we proposed a blind multichannel algorithm for a distributed detection system and applied those algorithms for multichannel seizure detection assuming that the local detectors were uncorrelated. However the existing seizure detection algorithms proposed by Liu, Gotman and Celka exploit similar temporal and/or frequency characteristics of the EEG signal and thus their decisions are most likely correlated. To this purpose we extend our previous approach to potentially account for possible correlation between local detector decisions. First, we formulate the set of nonlinear equations describing the probability density function of the decision vector. These equations express probabilities of particular decision vectors as functions of the unknown a priori probabilities of the binary hypotheses and the unknown probabilities of false alarm and missed detection. Then, we estimate these unknowns using the maximum likelihood estimator and Bahaduz-Lazarsfeld expansion of the density function. However it should be observed that the exact expression for the likelihood criterion involves infinitely large number of correlation coefficients and thus the problem is ill-posed. However in practice the higher-order correlations are often negligible and therefore we propose to approximate likelihood ratio criterion by using only second order correlations. In addition to simplifying computational procedure this significantly reduces the number of unknown parameters. The estimation is then done in two phases. During first phase we estimate correlation coefficients and the corresponding properties of the local detectors using seizure-free segments of EEG data. Using these results we then estimate the remaining parameters using segments of data where seizures are occurring. FInally we evaluate the performance of the proposed algorithm using a real data-set.

TP8a2-4

A Novel Approach to Automated Fetal Heart Rate Analysis

Shishir Dash, Petar Djuric, Stony Brook University

There exist several algorithms for automated fetal heart rate (FHR) analysis. In general, they lack specificity of detection and robustness against noise. Several interesting approaches that address some of these problems have been proposed over the years. A very recent method is based on the use of system-identification for quantifying the relationship between intra-uterine pressures (IUP) and FHR. Using the same model, we propose a Bayesian approach to estimating various unknowns including the IUP-FHR system parameters, predictions of response to contractions, and statistical correlations between changes in FHR variability and fetal fate. In addition, we aim at providing clinicians with confidence bounds on all the predictions, with a view to objectifying fetal diagnosis in the labor room. We demonstrate the performance of the proposed method on real data.

TP8a2-5
Joint Waveform and Firing Rate Spike-Sorting for Continuous Extracellular Traces
Brett Matthews, Mark Clements, Georgia Institute of Technology

This paper discusses recent work in automatic spike-sorting for continuous extra-cellular cortical traces. Our spike-sorting framework jointly models neuronal firing times and corresponding action potential waveforms as a discrete-state latent variable process. We model the likelihood of the observed firing occurrence times as the aggregation of multiple hidden point processes based on inter-arrival probability distributions. Action potential waveforms are modeled as a mixture of Gaussians. Clustering and parameter estimation are accomplished with an iterative, unsupervised procedure. Finally, we evaluate our procedure on partially labeled cortical traces obtaining a significant improvement over the waveform-only GMM procedure.

TP8a2-6
Statistical Design of Position-Encoded Microsphere Arrays at Low Target Concentrations
Xiaoxiao Xu, Washington University in St. Louis; Pinaki Sarder, Washington University School of Medicine in St. Louis; Arye Nehorai, Washington University in St. Louis

We design microsphere arrays with predetermined positions of microspheres, for capturing targets at low concentrations. To optimize the design parameters, we compute the Ziv-Zakai bound (ZZB) on the errors in estimating the target concentrations. We numerically demonstrate our design by computing the minimal distance between the microspheres and the optimal imaging temperature, for a desired level of errors. We also validate that, at low target concentrations, the statistical design using the ZZB is more precise than that using the posterior Cramer-Rao bound. We further quantitatively evaluate the effects of the fluorescence microscope point-spread function and the image sensor resolution on the design performance, which provide useful guides to the device design and implementation. The key advantages of the proposed microsphere arrays are error-free target identification, simplified data analysis, high packing density, and reduced cost.

TP8a2-7
Biosensor Arrays for Collaborative Detection of Analytes
Maryam Abolfath-Beygi, Vikram Krishnamurthy, University of British Columbia

Estimating the concentration of target molecules in a fluid flow over multiple sensors is a challenging inverse problem involving the advection diffusion partial differential equation (PDE) due to two non-standard features. Firstly, it involves parameter estimation in an infinite dimensional dynamical system. The PDE is coupled with Dirichlet and von-Neumann boundary conditions and cannot be solved analytically. Sec- ondly, since each sensor grabs target molecules it changes the concentration. Therefore, the measurement process affects the system state (concentration). This is highly unusual in a signal processing setting since in most signal processing models, measurements do not affect the system state. So to estimate the concentration, we need to construct a mathematical model to describe the effect of measurements on concentration. This paper deals with estimation of the concentra- tion of target molecules in a fluid when it flows past multiple biosensors. The fluid flow is modelled as an advection diffusion partial differential equation. Estimating the concentration from multiple biosensors then is equivalent to solving an inverse problem. We use averaging theory methods to approximate the model described by partial differential equation with a system of ordinary differential equations. The resulting nonlinear least squares problem is then solved numerically. We also use the new model to derive the mean squared estimation error of concentration analytically. As a case study, we illustrate our results on a biosensor built out of protein molecules to verify the accuracy of proposed method.

TP8a2-8
Developing Movement Direction Decoders from Local Field Potentials
Vijay Aditya Tadipatri, Ahmed H. Tewfik, The University of Texas at Austin; James Ashe, Guiseppe Pellizzer, VA Medical Center, Minneapolis

A main drawback of using Local Field Potentials (LFP) for Brain Computer Interface is their inherent instability and non-stationarity. In specific, even when a well-trained subject performs the same task over a period of time, the neural data observed is instable. To overcome the instability, it was proposed that qualitative information in the form of spatial patterns of inter-channel ranking of multi-channel LFP recordings be used for decoding movement directions. Further, the quality of the recording was also extracted by means of statistical distributions of the top powered channels and these distributions were instrumental in characterizing the movement directions. In this paper we extend the method by identifying direction specific spatial locations in the motor and the pre-motor cortex and then evaluating their spatio-temporal distribution of top ranked channels and analyzing the performance of the subject when a new task is introduced. In this process we prune the spatial locations to collect those that are tuned to a particular direction. This process will ensure that information specific to the direction is extracted. Preliminary results show promise and provide higher decoding power than traditional techniques. We also show that these methods outperform the existing state-of-the-art technique.

Session: TPa8 – Sensor Networks 1:30 PM – 3:10 PM

Chair: ***Soumya Kar,*** *Carnegie Mellon University*

TP8a3-1

Dual Trust Secure Protocol for Cluster-Based Wireless Sensor Networks

Yang Li, Melody Moh, San Jose State University

In addressing the unique security challenges faced by wireless sensor networks, this paper proposes a novel, two-level trust-based scheme. The solution is described on top of a well-known, cluster-based protocol, LEACH (Low Energy Adaptive Clustering Hierarchy), and is named DTSLEACH (Dual-Trust Secure LEACH). It includes authentication, confidentiality, integrity, and trust mechanisms. Performance evaluation shows that, compared with two other existing protocols, DTSLEACH provides strong performance in security, energy and memory efficiencies, as well as network throughput.

TP8a3-2

User Clustering and Energy Efficient Cooperation in Cellular Networks

Jinhong Wu, George Washington University; Harry (Zhibing) Chen, Yong Liu, Liyu Cai, Alcatel-Lucent Shanghai Bell

We consider user clustering and cooperative transmission in cellular networks. Several physically close users form a cluster to share a single channel for external communication with the base station. The internal information exchange among clustered users is provided by short range device-to-device communication that reuses cellular channels being used by remote clusters. A channel allocation scheme with frequency reuse within the cell is designed to minimize maximum intra-cell interference. We analyze feasible distance for cluster forming and maximum signal to interference and noise ratio due to frequency reuse in such an environment. Our analysis and simulations demonstrate the feasibility of and benefits from the proposed scheme.

TP8a3-3

Optimization of Exponential Error Rates for a Suboptimum Fusion Rule in Wireless Sensor Networks

John Gubner, University of Wisconsin-Madison; Louis Scharf, Edwin Chong, Colorado State University

A simple fusion rule with multiple thresholds is presented for a wireless sensor network to resolve multiple hypotheses. In contrast to the common assumption that the measurements are conditionally independent and identically distributed, only conditional independence under each hypothesis is assumed here. This allows modeling of situations in which different sensors have different local detection probabilities as well as communication links with different signal-to-noise ratios. It is shown that joint threshold optimization is not required in order to maximize the asymptotic decay rate of the average probability of error. Furthermore, it is easy to compute these individual thresholds numerically.

TP8a3-4

Collaborative Estimation in Dispersive Environments: A Frequency Domain Approach

Sriram Venkateswaran, Upamanyu Madhow, University of California, Santa Barbara

We investigate the feasibility of reconstructing a signal recorded at multiple sensors through dispersive channels, with minimal prior information regarding the signal and the channels. We propose a frequency domain algorithm which exploits the continuity of the channels across frequency, operating over small, overlapped frequency bins. The algorithm employs SVD-based estimates of the signal over each frequency bin , and then stitches these estimates together based on consistency conditions across adjacent bins. We demonstrate that the algorithm gives excellent performance, but also identify fundamental limitations arising due to multiple explanations consistent with the observed data.

TP8a3-5

Distributed Support Vector Machines in Sensor-Actuator Networks

Juo-Yu (Joseph) Lee, Kung Yao, University of California, Los Angeles

A conventional sensor network collects huge amounts of data that can be used to train a centralized support vector machine for classification purpose. However, a flat network structure that mandates sensors reporting data through one hop communication to a fusion cite may either require large bandwidth or incur significant energy expenditure. A more efficient alternative is supported by sensor-actuator networks that rely on actuators as resource-rich intercessors to reduce power consumption and maintain the overall task performance. We study a support vector machine with data distributed over a sensor-actuator network. Each sensor

performs a sensing task and reports data to a possible actuator. Each actuator collects data and trains a local support vector machine. Cooperation between actuators yields a near-optimal support vector machine, which is given by a centralized flat sensor network without the actuators.

TP8a3-6
Step-Size Sequence Design for Finite-Time Distributed Average Consensus
Alain Kibangou, University Joseph Fourier/CNRS

This paper studies the problem of distributed estimation of an unknown parameter vector using wireless sensor networks. As it is now well known, distributed estimation can be achieved using consensus algorithms. Except very few works, in general, consensus is asymptotically reached. In this paper, we design a set of Perron matrices in order to reach exact consensus in a finite number of steps given by the diameter of the communication graph. The design sequence proposed in this paper is based on the properties of the Bose-Mesner algebra of symmetric matrices with constant diagonal. Our results are restricted to distance regular graphs and required a network configuration step by a central network manager.

TP8a3-7
Target Localization in Sensor Networks with Quantized Data in the Presence of Byzantine Attacks
Keshav Agrawal, Aditya Vempaty, Indian Institute of Technology, Kanpur; Hao Chen, Boise State University; Pramod Varshney, Syracuse University

Wireless Sensor Networks (WSNs) are vulnerable to Byzantine attacks in which the malicious users send wrong data to the fusion center leading to an increase in the probability of incorrect location estimation. This paper considers Byzantine attacks in the location estimation problem in the wireless sensor networks where each sensor uses a binary quantization scheme to send their binary decisions to the fusion center. Posterior Cramer-Rao lower Bound(PCRLB) metric and Fisher Information Matrix (FIM) have been used to analyze the performance of the network in the presence of attacks. We have considered two kinds of attack strategies, independent attacks (all the malicious sensors attack a WSN independently of each other) and collaborative attacks (all the malicious sensors communicate with each other and attack the WSN together). We define and calculate the fraction of Byzantine attackers in the network above which the fusion center becomes incapable of finding the location of the target. Optimal attacking strategy for given attacking resources has also been proposed.

TP8a3-8
Uniformly Most Powerful Distributed Detection and its Application in Cooperative Spectrum Sensing
Hao Chen, Uri Rogers, Boise State University

Abstract--- In this paper, a special class of distributed composite binary hypothesis testing problem with monotonic likelihood ratio is investigated. The sensor observations are assumed to be conditionally independent given a fixed but unknown parameter \theta where \theta\in\Theta_{1} under the H_{1} hypothesis and \theta=\theta_{0} under the H_{0} hypothesis. The optimal form of sensor decision rule is established under the Neyman-Pearson criterion. As an illustrative example, the design of an optimal cognitive radio rule for cooperative spectrum sensing is established.

Track C. Networks
Session: TPa8 – Wireless Networks **1:30 PM – 3:10 PM**
Chair: ***Vivek Cadambe,*** *University of California, Irvine*

TP8a4-1
Dynamic Pricing under Binary Demand Uncertainty: A Multi-Armed Bandit with Correlated Arms
Yixuan Zhai, Qing Zhao, University of California, Davis

We study a special case of dynamic pricing problem, in which the underlying demand model is unknown and can take one of two possible forms. We show that the problem can be considered as a multi-armed bandit problem with correlated arms. We develop dynamic pricing policies that achieve a constant regret where regret is defined as the revenue loss with respect to the case with known demand model over an infinite horizon. We reveal an interesting connection of this dynamic pricing problem with the binary detection problem and show that choosing prices with large Kullback-Leibler divergence at initial steps reduces regret.

TP8a4-2
Optimal Routing with Mutual Information Accumulation in Wireless Networks
Rahul Urgaonkar, Raytheon BBN Technologies; Michael Neely, University of Southern California

We study the problem of minimum delay routing in multi-hop wireless networks with rateless codes. Rateless codes allow each node of the network to accumulate mutual information from every packet transmission. This enables a significant performance gain over conventional shortest path routing. Further, it outperforms cooperative communication techniques that are based on energy accumulation. However, determining the minimum delay routing solution requires complex and combinatorial networking decisions concerning which nodes participate in transmission, and which decode ordering to use. We identify several structural properties of the optimal solution to simplify the problem and derive an optimal greedy algorithm. Although the reduced problem still has exponential complexity, unlike prior works on such problems, our greedy algorithm is simple to use and does not require solving any linear programs. Further, using the insight obtained from the optimal solution to a line network, we propose two simple heuristics that can be implemented in polynomial time in a distributed fashion and compare them with the optimal solution. Simulations suggest that both heuristics perform very close to the optimal solution over random network topologies.

TP8a4-3
Optimal Scheduling of Real-Time Messages in Peer-to-Peer Wireless Networks
Juan Jose Jaramillo, Shihuan Liu, Lei Ying, Iowa State University

This paper studies the problem of service allocation and scheduling of real-time messages in peer-to-peer wireless networks. Using stochastic network theory and optimization we propose a model that allows us to design a dynamic service allocation algorithm that maximizes the total network utility while meeting deadline constraints, by appealing to connections between Lagrange multipliers and deficits in service. The model allows for general interference constraints and arrival models. Using simulations we compare our algorithm against an optimal solution proposed for scheduling persistent real-time traffic and show the limitations of that approach to handle real-time messages for providing fairness.

TP8a4-4
State-Based Single Channel Selection in Multi-Channel Wireless Networks
Brian Phillips, Murali Tummala, John McEachen, Naval Postgraduate School

We present a scheme for identifying and selecting high performing channels in a multi-channel wireless network through the application of a state based approach. The proposed scheme can increase throughput and reduce delay. One widely implemented channel selection scheme is random selection which can lead to suboptimal network performance when one or more data channels are disadvantaged. Our proposed channel selection scheme is shown to overcome the inefficiency of random selection. We develop a theoretical performance model of our state based selection scheme and compare it against random selection. We then present simulation results to demonstrate a significant reduction in transmission errors by state based over random selection.

TP8a4-5
Robust Joint Transceiver Beamforming for Cognitive Radio Network
Huiqin Du, Tharmalingam Ratnarajah, Queen’s University Belfast; C. B. Papadias, Athens Information Technology

This paper considers the spectrum sharing multiple-input multiple-output (MIMO) cognitive radio network, in which multiple primary users (PUs) coexist with multiple secondary users (SUs). Joint transceiver cognitive beamforming design is introduced to minimize the transmit power of the SU base station (SBS) while simultaneously targeting lower bounds on the received signal-to-interference-plus-noise ratio (SINR) for the SUs and imposing upper limits on the interference temperature to the PUs. With the perfect knowledge of all links, the optimal secondary transceiver beamforming is obtained iteratively. Due to the limited cooperation between SBS and PUs, perfect information of primary links may not be available at SBS which could lead to severe interference to the PUs. Robust design is developed against the uncertainties in the primary links by keeping the interference to the PU below a pre-specified threshold with high probability. Simulation results are presented to validate the effectiveness of the proposed algorithms.

TP8a4-6
Probabilistic Power Control for Heterogeneous Cellular Networks with Closed-Access Femtocells
Ralf Bendlin, Yih-Fang Huang, University of Notre Dame; Josef A. Nossek, Munich University of Technology

Heterogeneous cellular networks where conventional macro cells are overlaid with low power consumer deployed femtocell base stations are in the process of being deployed for their benefits in terms of scale, economy, and spectral efficiency. However, when femtocells operate in closed access, the problem of coverage holes for macro users needs to be solved. This paper proposes a probabilistic power control scheme based on results from stochastic geometry. The femto-layer transmit power for a given

cell is computed at its macro base station and broadcasted to the femto base stations. Simulation results unveil that considerable performance gains can be achieved without additional information exchange among base stations or measurements at the handsets.

TP8a4-7
Pricing and Bandwidth Allocation Problems in Wireless Multi-Tier Networks
Camila Maria Gabriel Gussen, Universidade Federal do Rio de Janeiro; Elena Veronica Belmega, Mérouane Debbah, Supélec

Future cellular networks are facing crucial architecture changes to cope with high throughput, energy and cost-efficiency demands. Emerging solutions are small-cells and femtocells which will coexist with classical macro-cell technology. In these heterogeneous networks, we study the joint service pricing and bandwidth allocation problem at the operator level. Each user selfishly adopts the service that optimizes its satisfaction. The user-level problem is formulated as a non-atomic game. The Wardrop equilibrium is proven to exist and an analytical expression is provided for arbitrary number of services. The equilibria multiplicity, the influence of prices and bandwidth allocation policies are investigated numerically.

TP8a4-8
Joint Power and Rate Control for Coded Wireless Packet Networks
Ketan Rajawat, Nikolaos Gatsis, Emiliano Dall'Anese, Georgios B. Giannakis, University of Minnesota

Ad hoc networks are fast becoming indispensable for infrastructure-less environments encountered with e.g., remote sensing, combat support, search-and-rescue, and mesh networks. These volatile operational environments place severe restrictions on the bandwidth and power resources available to wireless nodes. To promote an efficient use of spectral resources, and guarantee high end-to-end performance goals, this paper leverages network coding to design network utility maximization (NUM) protocols for wireless ad hoc networks. A cross-layer approach is developed for obtaining optimal transmit-powers, and rates at the network and application layers. To account for interference and propagation effects, per-link outage probability constraints are also incorporated in the cross-layer NUM framework. Corroborating simulations illustrate the merits of the novel algorithms.

Track D. Signal Processing and Adaptive Systems
Session: TPb8 – Machine-Learning-Based Statistical Signal Processing 3:30 PM – 5:10 PM
Chair: ***Phil Schniter,*** *The Ohio State University*

TP8b1-1
Shrinkage Fisher Information Embedding of High Dimensional Feature Distributions
Xu Chen, Yilun Chen, Alfred O. Hero, University of Michigan

In this paper, we introduce a dimensionality reduction method that can be applied to clustering of high dimensional empirical distributions. The proposed approach is based on stabilized information geometrical representation of the feature distributions. The problem of dimensionality reduction on spaces of distribution functions arises in many applications including hyperspectral imaging, document clustering, and classifying flow cytometry data. Our method is a shrinkage regularized version of Fisher information distance, that we call shrinkage FINE (sFINE), which is implemented by Steinian shrinkage estimation of the matrix of Kullback Liebler distances between feature distributions. The proposed method involves computing similarities using shrinkage regularized Fisher information distance between probability density functions (PDFs) of the data features, then applying Laplacian eigenmaps on a derived similarity matrix to accomplish the embedding and perform clustering. The shrinkage regularization controls the trade-off between bias and variance and is especially well-suited for clustering empirical probability distributions of high-dimensional data sets. We also show significant gains in clustering performance on both of the UCI dataset and a spam data set. Finally we demonstrate the superiority of embedding and clustering distributional data using sFINE as compared to other state-of-the-art methods such as non-parametric information clustering, support vector machine (SVM) and sparse K-means.

TP8b1-2
Adaptive Learning of Immunosignaturing Peptide Array Features for Biothreat Detection and Classification
Anna Malin, Jun Jason Zhang, Bhavana Chakraborty, Narayan Kovvali, Antonia Papandreou-Suppappola, Stephen Johnston, Phillip Stafford, Arizona State University

As recently discovered, a comprehensive profiling of the antibodies in a person can be obtained using random sequences of peptide arrays. Using such immunosignatures to extract appropriate stochastic features, we propose a novel, reference-free, adaptive learning methodology for biothreat detection and classification. The technique is based on a learning-while-classifying approach to adaptively detect new biothreat agents. We demonstrate the success of our approach using real experimental data.

TP8b1-3
Sparse Classification of RF Transients Using Chirplets and Learned Dictionaries
Daniela Moody, Steven Brumby, Kary Myers, Norma Pawley, Los Alamos National Laboratory

Detection and classification of radiofrequency transients in high noise and clutter environments is important in persistent surveillance applications. Conventional methods using orthonormal bases can be suboptimal for transient classification, and do not usually lead to sparse features. We propose two alternative approaches based on dictionaries adapted to data. A first option is using analytical, over-complete dictionaries, which yield sparse representations by design. A second option is learning discriminative under-complete dictionaries directly from data. A pursuit search over either dictionary generates sparse classification features. We present comparative classification performance on simulated test data, and discuss robustness to noise and clutter.

TP8b1-4
Exploiting Random Matrix Theory to Improve Subspace-Based Classification
Nicholas Asendorf, Raj Rao Nadakuditi, University of Michigan

We consider a binary subspace-based classification problem in high-dimensions where PCA is applied to limited, noisy labeled training data to estimate the low-dimensional signal subspaces for each class. In moderate to low signal-to-noise ratio (SNR) settings, the performance degrades because of subspace estimation errors due to limited training samples. We use random matrix theory to develop an optimal classifier that improves classification performance by accounting for these estimation errors. We use simulations to illustrate the improvement in performance relative to the plug-in classifier for all values of SNR and target false-positive rates.

TP8b1-5
Non-Linear Unmixing of Hyperspectral Images with Kernels
Jie Chen, Université de Technologie de Troyes; Cédric Richard, Université de Nice Sophia-Antipolis; Paul Honeine, Université de Technologie de Troyes

In hyperspectral images, pixels are mixtures of spectral components associated to pure materials, called endmembers. Recently, to overcome the limitations of the linear model, nonlinear unimixing techniques have been proposed in the literature. In this paper, nonlinear hyperspectral unmixing problem is studied through kernel-based learning theory. Endmember components at each spectral band are mapped implicitly in a high feature space, in order to address nonlinear interactions of photons. Experiment results with both synthetic and real images illustrate the effectiveness of the proposed scheme.

TP8b1-6
Modulation Classification of MIMO-OFDM Signals by Independent Component Analysis and Support Vector Machines
Handan Agirman-Tosun, Alexander M. Haimovich, Osvaldo Simeone, New Jersey Institute of Technology; Wei Su, U.S. Army CERDEC Aberdeen Proving Ground; Jason Dabin, U.S. Navy SPAWAR SCP; Emmanuel Kanterakis, CACI International

A modulation classification scheme based on Independent Component Analysis (ICA) and Support Vector Machines (SVM) is proposed for MIMO-OFDM signals over frequency- selective, time- varying channels. The processing has two main phases: blind separation of the MIMO streams, followed by modulation classification of the separated signals. Blind signal separation is achieved by applying the ICA JADE algorithm. Subsequently, modulation classification is implemented as a SVM based on preselected cumulant features. The proposed method is applied to classification of MIMO- OFDM QPSK and 16- QAM signals, and it shown to yield high probabilities of correct classification over standard, slow and fast fading ITU channels.

TP8b1-7
A Measure of Difference between Discrete Sample Sets
Debejyo Chakraborty, General Motors Company; Narayan Kovvali, Arizona State University

The estimation of statistical distance between populations is a task of importance for many applications. Conventional methods often rely on the use of a maximum-likelihood (ML) estimator, usually due to its analytical and computational simplicity. However, the ML point estimate provides no information about the uncertainty in the parameters and distance estimated, which grows with lesser amounts of observed data. In this paper, a new measure is developed for statistical difference between finite sized sample sets of discrete observations. The measure is defined as the expected distance between discrete probability distribution functions (pdfs), with the expectation carried out over Dirichlet posteriors on the pdfs given the observed samples. In contrast to conventional ML estimates of distance, this approach by-design accounts for the uncertainty due to the finite size of the observation sets. In the limit of infinite number of observation samples, the expected distance simplifies to the ML estimate. For finite and small sized sample sets, the expected distance yields a more reliable measure of statistical difference.

TP8b1-8
On l1 Mean and Variance Filtering
Bo Wahlberg, Cristian R. Rojas, Mariette Annergren, KTH Royal Institute of Technology

We study an l1 regularized maximum likelihood method, related to the fused lasso method and l1 trend filtering, to segment a time series with respect to variations in both the mean and the variance. The model parametrization is based on the inverse of the variance and allows the parameters to vary at each sampling instance. To penalize variations in the estimate, the l1-norm of the time difference of the parameters is used as a regularization term. We derive an explicit expression of the maximum regularization control parameter lambda, and an intuitive method for solving the corresponding convex optimization problem.

Track C. Networks
Session: TPb8 – Network Information Theory 3:30 PM – 5:10 PM
Chair: ***Daniela Tuninetti,*** *University of Illinois at Chicago*

TP8b2-1
Information-Theoretic Limits of Dense Underwater Networks
Won-Yong Shin, Harvard University; Daniel Lucani, Universidade do Porto; Muriel Medard, Massachusetts Institute of Technology; Milica Stojanovic, Northeastern University; Vahid Tarokh, Harvard University

Information-theoretic throughput scaling laws are analyzed in an underwater acoustic network with n regularly located nodes on a unit square, in which both bandwidth and received signal power can be severely limited. A narrow-band model is assumed where the carrier frequency is allowed to scale as a function of n. We first characterize an attenuation parameter that depends on the frequency scaling as well as the transmission distance. In the dense network having unit area, a cut-set upper bound on the capacity scaling is then derived. We show that there exists either a bandwidth or a power limitation, or both, according to the path-loss attenuation regimes, thus yielding the upper bound that has three fundamentally different operating regimes. In the dense network, we also describe an achievable scheme based on the simple nearest-neighbor multi-hop transmission. The operating regimes that guarantee the order optimality are identified, where frequency scaling is instrumental towards achieving the order optimality in the regimes.

TP8b2-2
A Two-Way Secrecy Scheme for the Scalar Broadcast Channel with Internal Eavesdroppers
Chee Yen Leow, Imperial College London; Dennis L. Goeckel, University of Massachusetts; Kin K. Leung, Imperial College London

In a broadcast channel where idle users are internal eavesdroppers, the secrecy capacity approaches zero when the number of users is large. We propose a two-way secrecy scheme to improve the secrecy capacity and analyse it in large network. The proposed scheme makes use of the forward and backward channels to transmit a secret key and a one-time pad encoded secret message. Relays are also used to prevent the eavesdropper from gaining an advantage of multi-user diversity. Analytical and simulation results justify that the proposed two-way secrecy scheme achieves positive secrecy rate even when the number of users approaches infinity.

TP8b2-3

Relaying for Multiple Sources in the Absence of Codebook Information

Ye Tian, Aylin Yener, Pennsylvania State University

This work investigates the optimality of compress-and-forward (CF) type relaying in wireless networks when the relay does not know the codebooks used by the sources. The relay is called oblivious for this reason. The relay-destination links are assumed to be out-of-band with finite capacity. We study two multi-source relay networks, namely the multiple access relay channel (MARC) and the interference relay channel (IFRC), both with an oblivious relay. For the MARC with an oblivious relay, we derive a new outerbound and show that the capacity region can be established using a generalized CF (GCF) scheme, where the destinations jointly decode the compression indices and the source messages. In particular, we show that, for multi-source relay networks, GCF scheme achieves higher individual rates than CF scheme with sequential decoding of compression indices and source messages. For the IFRC with an oblivious relay, we focus on the case where the destinations know all the codebooks used by the sources. We establish a new strong interference condition, under which we derive a new outerbound and show that it is achievable using GCF scheme, thus establishing the capacity region of IFRC with an oblivious relay.

TP8b2-4

Compound Codes for Optimal Repair in MDS Code Based Distributed Storage Systems

Viveck Cadambe, University of California, Irvine; Cheng Huang, Microsoft Research; Jin Li, Sanjeev Mehrotra, Microsoft Research Redmond

In this paper, we study maximum distance separable (MDS) codes for distributed storage with optimal repair properties. Previously, (n,k) MDS codes have been constructed to store data in n storage nodes, such that the system can tolerate the failure of any $(n-k)$ storage nodes because of the MDS property. Further, such MDS codes have been constructed which satisfy an additional optimal repair property as follows: the failure of a single storage node can be repaired by downloading a fraction of $1/(n-k)$ of every surviving storage node. In previous constructions satisfying this optimal repair property, the size of the code is polynomial in k for the low-redundancy regime of k/n \leq 1/2, but the codes have an exponential size (w.r.t. k) for the practically more relevant high-redundancy regime of $k/n > 1/2$. In this paper, we construct polynomial size MDS codes with optimal repair of a single failed node in this high redundancy regime for the special case where $k/n = 2/3>1/2$. Our codes construction with optimal repair properties for $n=3k/2$ is obtained by combining two underlying $(k,k/2)$ codes, with each underlying code being an MDS code satisfying the optimal repair property. Finally, our idea can be generalized to compound m $(\overline{k},\overline{k}/2)$ codes to obtain a $(n=(m+1) \overline{k}, m\overline{k})$ code with optimal repair.

TP8b2-5

Effects of Range Expansion and Interference Coordination on Capacity and Fairness in Heterogeneous Networks

Sayandev Mukherjee, Ismail Guvenc, DoCoMo USA Labs

Range expansion (RE) and inter-cell interference coordination (ICIC) can improve the capacity and fairness of heterogeneous networks (HetNets) by off-loading macrocell users to low-power nodes like picocells or femtocells. Owing to the difficulty in analytical treatment, current studies for RE and ICIC in HetNets rely mostly on simulations. In this work, we begin with a description of a statistical model for locations of the base stations (BSs) and users (UEs). We then demonstrate analytically the off-loading benefits of HetNets through using the cumulative distribution functions (CDFs) of the signal to interference plus noise ratio (SINR) difference between the macrocell and strongest picocell or femtocell signals. These CDFs are then used to investigate the capacity and fairness for arbitrary values of the RE bias, and benefits of using ICIC with RE are demonstrated.

TP8b2-6

An Extended Etkin-Type Outer Bound on the Capacity of the Gaussian Interference Channel

Anas Chaaban, Aydin Sezgin, University of Ulm

Several genie-aided approaches have been used in the past to derive capacity outer bounds for the interference channel. In this paper, we provide an outer bound based on the genie-aided approach devised by Etkin for upper bounding the sum-rate. Namely, we extend Etkin's bound to upper bound a weighted sum-rate, which yields an outer bound on the capacity region. Some previously known bounds are special cases of the obtained outer bound, and hence the new bound is tighter. We also derive some bounds on the genie parameters, which must be satisfied in order to obtain a non-trivial bound.

TP8b2-7
Communication Strategies to Ensure Generic Networked Observability in Multi-Agent Systems
Mohammadreza Doostmohammadian, Usman A. Khan, Tufts University

In this paper, we consider the state estimation in linear dynamical systems when their observations are distributed over a network of agents. We provide a Networked Kalman Filtering (NKF) approach exploring both state and observation fusion. Assuming global observability, we study the structure of the agent communication network in order to stabilize the networked estimation error. In particular, we use structured systems theoretic methods to show that the underlying network may recover observability of locally unobservable agents when the system matrices have full structured rank. In this context, we provide strategies to design communication among the agents and study the effectiveness of these links towards networked observability.

TP8b2-8
Error Probability Bounds for Binary Relay Trees with Unreliable Communications
Zhenliang Zhang, Ali Pezeshki, Colorado State University; William Moran, University of Melbourne; Stephen Howard, Defence Science and Technology Organization; Edwin Chong, Colorado State University

We study the decentralized detection problem in the context of balanced binary relay trees. We assume that the communications in the tree network fail with certain probabilities. We show that the step-wise reduction of the total detection error probability is slower than the case where the network has no communication failures. We derive that, under the assumption of identical link failure probability in the tree, the decay of the total error probability at the fusion center is o(\sqrt{N}) in the asymptotical regime. In addition, if the given link failure probabilities decrease to 0 as links get closer to the fusion center, then the decay exponent of the total error probability is \sqrt{N}, provided that the decay of the failure probabilities is sufficiently fast.

Track B. MIMO Communications and Signal Processing
Session: WAa1 – Channel Estimation for Multi-Antenna Systems
Chair: ***Jakob Hoydis,*** *Supélec*

WA1a-1 8:15 AM
Close-Range Outdoor Wireless Channel Sounding
Scott E. Johnston, Paul D. Fiore, MIT Lincoln Laboratory

A data collection in the 2.4GHz ISM band was performed in order to characterize the coupling between a colocated transmitter and receiver in a time-varying, frequency-selective, wideband outdoor channel. Once least-squares channel estimates are obtained, channel length, RMS delay spread, coherence time, and coherence bandwidth are calculated. The values help assess the effects of line-of-sight (LOS) versus non-line-of-sight (NLOS) and traffic conditions, and are being used to inform the design of an advanced adaptive communications system.

WA1a-2 8:40 AM
Channel Aging Effects in CoMP Transmission: Gains from Linear Channel Prediction
Lars Thiele, Bho Matthiesen, Michael Olbrich, Konstantinos Manolakis, Slawomir Stanczak, Fraunhofer Heinrich Hertz Institute

Cooperative transmission from multiple base stations (BSs) in the multi-cellular system is known to reduce the effects from cochannel interference (CCI). By exploiting channel adaptive spatial precoding we can actively reduce the interference inside a cluster of cooperating BSs, denoted as coordinated multipoint (CoMP) transmission. Despite the fact of using zero-forcing (ZF) beamforming (2), practical systems will always suffer from intra-cluster interference. There is a variety of reasons which destroy the inter-user orthogonality: Channel estimation and quantization, channel aging effects and synchronization errors of multiple BSs. The contribution of this work is to evaluate the effects caused by channel aging. Therefore, we first concentrate on 1-dimensional channel prediction methods, their tracking performance and beneficial property in reducing the mismatch between the precoder and the channel. We will conclude with an extrapolation towards system level performance of CoMP.

WA1a-3 **9:05 AM**

A Modified Compressed Sampling Matching Pursuit Algorithm on Redundant Dictionary and Its Application to Sparse Channel Estimation on OFDM

Chulong Chen, Michael Zoltowski, Purdue University

This paper proposes a modified compressed sensing algorithm for sparse multipath channel estimation in wideband OFDM systems. By using a virtual channel representation, the sparse nature of a multipath channel is revealed and exploited. Unlike other proposed sparse channel estimation schemes, it is noted that a truly sparse assumption on the channel impulse response (CIR) must factor in the leakage of energy of each multipath component resulting from bandpass filtering and the resulting limited bandwidth. We propose to represent the CIR as a strongly correlated redundant frame so that the representation is truly sparse. However, the introduction of correlated frames complicates the canonical compressed sensing problem. A model-based modification to CoSaMP algorithm is thus proposed for recovering the CIR. Simulation results are presented indicating a significant improvement over straightforward application of canonical compressed sensing techniques.

WA1a-4 **9:30 AM**

Asymptotic Analysis of Double-Scattering Channels

Jakob Hoydis, Romain Couillet, Mérouane Debbah, Supélec

We consider a multiple-input multiple-output (MIMO) multiple access channel (MAC), where the channel between each transmitter and the receiver is modeled by the doubly-scattering channel model. Based on novel techniques from random matrix theory, we derive deterministic approximations of the mutual information, the signal-to-noise-plus-interference-ratio (SINR) at the output of the minimum-mean-square-error (MMSE) detector and the sum-rate with MMSE detection, which are almost surely tight in the large system limit. Moreover, we derive the asymptotically optimal transmit covariance matrices. Our simulation results show that the asymptotic analysis provides very close approximations for realistic system dimensions.

Track E. Array Signal Processing

Session: WAb1 – MIMO Radar and SAR

Chair: ***Benjamin Friedlander,*** *University of California, Santa Cruz*

WA1b-1 **10:15 AM**

On Spatial Processing in MIMO Radar

Benjamin Friedlander, University of California, Santa Cruz

We develop a signal model for MIMO radar which takes into account delay and Doppler mismatch due to the fact that scatterers do not generally lie in the center of delay/Doppler resolution cells, as is almost universally assumed in the literature on this subject. It is shown that this mismatch causes a distortion of the array manifold thus impacting the results of array processing functions such as beamforming, null steering, direction finding and so on.

WA1b-2 **10:40 AM**

Subspace Fitting Based Autofocus for Stripmap SAR

Roger West, Jacob (Jake) Gunther, Todd Moon, Utah State University

There are many autofocus algorithms available for correcting uncompensated residual phase errors in SAR data. Most of these algorithms depend on the SAR modality (i.e. spotlight, stripmap, etc.). In this paper, we develop a mathematically principled model-based phase error estimation method for stripmap SAR. The proposed phase estimation method uses classical subspace fitting techniques that are well known in the array processing literature. It is shown that the proposed method is non-iterative in the sense that iterations between the image domain and the range compressed domain are not required in order to obtain the phase error estimates. As the derivation shows, the image does not need to be formed in order to obtain the phase error estimates.

WA1b-3 **11:05 AM**

Doppler Estimation and Compensation in MIMO Radar with Unitary Waveform Scheduling

Tariq Qureshi, Michael Zoltowski, Purdue University; Robert Calderbank, Duke University

In this paper, we present a method of detecting the range and Doppler phase of a point target using multiple antennas. As a key illustrative example, we consider a 4×4 system employing a unitary matrix waveform set, e.g., formed from Golay complementary sequences. When a non-negligible Doppler shift is induced by the target motion, the waveform matrix formed from the complementary sequences is no longer unitary, resulting in significantly degraded target range estimates. To solve this problem, we adopt a subspace based approach exploiting the observation that the receive matrix formed from matched filtering

of the reflected waveforms has a (non-trivial) null-space. Through processing of the waveforms with the appropriate vector from the null-space, we can significantly improve the range detection performance. Also, another very important target aspect is the velocity with which the target is moving, and to determine that, the exact Doppler phase shift induced by the target motion needs to be estimated with reasonable accuracy. To accomplish this task, we develop a strategy that uses multiple frequency estimation algorithms to estimate the Doppler phase, and we use simulations to show that the phase estimated obtained is reasonably accurate even at low SNRs.

WA1b-4 **11:30 AM**

On the Use of Fractional Autocorrelation to Correct Mismatches for Chirp Scale Focusing for Real SAR Image Formation

Judith Northrop, Antonia Papandreou-Suppappola, Arizona State University

The fractional Fourier transform (FrFT) was shown to be an effective processing technique for synthetic aperture radar (SAR). It was also used to enhance the focusing capabilities of the chirp scaling algorithm (CSA) for SAR image formation. We propose to use the fractional autocorrelation function in a local optimization procedure to detect possible mismatches before CSA focusing. As we will demonstrate, this increases SAR image quality.

Track A. Communications Systems

Session: WAa2 – OFDM

Chair: ***Antonia Maria Tulino,*** *Bell-Labs*

WA2a-1 **8:15 AM**

Low Complexity EM-Based Decoding for OFDM Systems with Impulsive Noise

Marcel Nassar, Brian Evans, The University of Texas at Austin

Modern OFDM systems such as cellular LTE and powerline communications experience additive impulsive noise emitted from their environment. OFDM modulation has been shown to provide resilience to impulsive noise due to its code diversity. However, typical OFDM receivers designed under the Gaussian noise assumption will lead to suboptimal performance due to the dependence in noise statistics across subcarriers resulting from the FFT operation. As a result, optimal detection of OFDM symbols becomes prohibitive due to its exponential complexity. We consider the design of a practical class of OFDM receivers that are constrained to perform independent detection on each subcarrier. In this paper, we propose an EM based low-complexity iterative decoding algorithm for OFDM systems in impulsive noise environments that preserves the independent decoding across subcarriers. Then we validate its performance under typical impulsive noise conditions based on noise traces collected from wireless and powerline platforms. Our proposed method achieves a gain between 2-7dB over the conventional OFDM receiver depending on the SNR range.

WA2a-2 **8:40 AM**

Accurate Characterization and Compensation of Phase Noise in OFDM Receiver

Pramod Mathecken, Taneli Riihonen, Stefan Werner, Risto Wichman, Aalto University

Phase noise compensation for OFDM based wireless systems is a necessary task to be performed in order to achieve good performance using cheap components in the transceiver electronics. Previous works on phase noise compensation typically utilize second-order statistics of the phase noise process and more importantly assume that the inter-carrier interference can be modeled as a Gaussian process. However, this assumption is valid only for large bandwidths of phase noise process which is rarely seen in practice since phase noise bandwidths can generally be kept much smaller. Our goal, in this paper, is to accurately characterize the phase noise in terms of the probability density function of the discrete Fourier transform of the complex exponential of the phase noise process. With this prior knowledge of the probability density function, we derive an accurate phase noise compensation method.

WA2a-3 **9:05 AM**

Linear Programming for Tone Reservation based IM/DD Optical OFDM Communications

Liang Chen, NICTA Victoria Research Laboratory; Yusheng Ji, National Institute of Informatics; Brian Krongold, Jamie Evans, NICTA Victoria Research Laboratory

This paper investigates the use of tone reservation for optical orthogonal frequency-division multiplexing (OFDM) system in a short-range intensity-modulated, direct-detected (IM/DD) channel. Some of the tones/subchannels are reserved to produce a negative peak cancellation signal that guarantees a unipolar output. This eliminates the need of additional biasing and clipping, and hence produces no in-band and out-of-band distortions. A linear programming (LP) approach is proposed to optimally solve the frequency-domain signal design problem. Simulation result suggests that this method offers greater flexibilities and a better trade-off between power and spectral efficiencies for a given link budget.

WA2a-4 **9:30 AM**

Analytical Link Performance Evaluation of LTE Downlink with Carrier Frequency Offset

Qi Wang, Markus Rupp, Vienna University of Technology

In this paper, we evaluate the link performance of a practical OFDM system, namely LTE downlink, with imperfect frequency synchronization. The analytical expression of the post-equalization SINR is derived and compared with results obtained from a standard compliant simulator. An excellent agreement is obtained. Due to the fact that equalization is carried out based on the constant channel knowledge within one subframe, other than the inter-carrier interference, the common phase error introduced by the residual carrier frequency offset degrades the SINR severely. This implies that in order to eliminate the link performance loss, frequency synchronization of rather high accuracy is required.

Track E. Array Signal Processing

Session: WAb2 – Beamforming

Chair: ***Michael Joham,*** *Technical University Munich*

WA2b-1 **10:15 AM**

Design of Beamforming in the Satellite Downlink with Static and Mobile Users

Andreas Gründinger, Michael Joham, Wolfgang Utschick, Technische Universität München

We consider the downlink (DL) of a satellite communication system, where a satellite equipped with a large number of antenna elements conveys information to single-antenna mobile receivers and static users on the earth's surface, i.e., the DL is modeled as a vector broadcast channel (BC). While for the static users perfect channel state information (CSI) is a valid assumption, only the statistics of the channels to mobile users are known to the satellite due to the large round-trip time. As a specialty of satellite communications, the channel covariance matrices of the statistical CSI users are rank-one. In this scenario, we design beamforming techniques that are capable to deal with full CSI users and statistical CSI users simultaneously. Unfortunately, we cannot resort to efficient strategies that are known for the purely complete CSI vector BC due to the lack of a general BC to multiple access channel (MAC) rate duality for statistical transmitter CSI. However, a sufficiently large number of transmit antennas enables us to employ zero-forcing (ZF) techniques with regard to the mobile users. For the remaining static users, a duality w.r.t. the signal-to-interference-and-noise-ratio (SINR) between the resulting vector BC and an appropriately constructed vector MAC is established. Based on the observation that an interference function can be defined in the dual vector MAC that is standard, iterative solutions for the quality-of-service power minimization and the rate balancing problem are found.

WA2b-2 **10:40 AM**

Array and Beamformer Design for Optimal Directivity

Jean Jacques Fuchs, Université de Rennes 1

In the conventional beamformer, the signals from the different elements of the array are delayed and weighted before being combined. By choosing adequately the weights, one typically controls the main lobe width and the side lobe levels to favor a particular direction while rejecting noise and potential jammers. The weights depend upon the optimality criterion and the sensor locations. In this contribution, the sensor locations are to be optimized as well. For a given number of sensors, one builds the linear array that allows to achieve the beampattern with the smallest side lobe level for a given main lobe width. For a given number of sensors, one seeks simultaneously the optimal array length, sensor locations and weights.

WA2b-3 **11:05 AM**

Coordinating Complementary Waveforms for Sidelobe Suppression

Wenbing Dang, Ali Pezeshki, Colorado State University; Stephen Howard, Defence Science and Technology Organisation; William Moran, University of Melbourne; Robert Calderbank, Duke University

We present a general method for constructing radar transmit-receive pulse trains whose cross-ambiguity functions are free of range sidelobes inside a desired Doppler interval. The transmit pulse train is constructed by coordinating the transmission of a pair of Golay complementary waveforms across time according to a binary sequence P. The receiver pulse train is constructed in a similar way, in terms of sequencing the Golay waveforms, but each waveform in the pulse train is weighted according to an integer sequence Q. We show that the spectra of the P and Q sequences control the size of the range sidelobes of the cross-ambiguity function and by shaping the two spectra we clear out range sidelobes inside a desired Doppler interval.

WA2b-4 **11:30 AM**

Robust Transmit Nulling in Phased Array Antennas

Peter Vouras, Jean DeGraaf, Naval Research Laboratory

The ability to create nulls in the transmit pattern of a phased array antenna has many applications for radar systems, including interference and clutter mitigation. Most nulling techniques introduce small perturbations in amplitude and phase, or phase-only, at each element of the phased array. For practical reasons, phase-only perturbations are desired and they create acceptable rms levels of null depth. However, the phase shift at each element will vary with the frequency of the transmitted signal. As a result, the depth and pointing accuracy of the transmit null will not be uniform over the bandwidth of the transmitted signal. This paper will describe some of the inherent limitations in achieving robust transmit nulling performance over a wide bandwidth when using phase-only, open-loop control on a typical phased array antenna. Some solutions to overcome these limitations and improve the performance of transmit nulls will be proposed.

Track D. Signal Processing and Adaptive Systems

Session: WAa3 – Information Theoretic Signal Processing

Chair: ***John Walsh,*** *Drexel University*

WA3a-1 **8:15 AM**

Modeling Noisy Feedback in Decentralized Self-Configuring Networks

Samir Medina Perlaza, Mérouane Debbah, Supélec

This paper introduces a generalization of the notion of Nash equilibrium (NE), namely quantal response equilibrium (QRE). In the QRE, radio devices choose their transmit/receive configuration taking into account that the estimation of their own performance contains a noise component. Here, it is shown that the notion of QRE neatly models decentralized self-configuring networks (DCSN) where feedback messages are impaired by quantization noise or decoding errors. The main contribution of the paper is twofold. First, we show that under the presence of noise in the estimation of the achieved performance, classical dynamics such as best response, fictitious play and reinforcement learning do not converge to equilibrium. Second, we introduce a learning technique which is robust against the presence of noise and converges to equilibrium in certain classes of games. We present numerical results in the context of a 2-dimensional parallel interference channel with two transmitters aiming to maximize their individual spectral efficiency by tuning the power allocation policy.

WA3a-2 **8:40 AM**

Local Failure Localization in Large Sensor Networks

Romain Couillet, Supélec; Walid Hachem, CNRS-Telecom ParisTech

In this article, the joint fluctuations of the extreme eigenvalues and eigenvectors of a large dimensional sample covariance matrix are analyzed when the associated population covariance is a finite-rank perturbation of the identity matrix. It is shown that these fluctuations are asymptotically normal with zero mean and a variance which is derived explicitly. This result is used in practice to develop an original framework for local failure localization in large sensor networks, among which sudden parameter changes.

WA3a-3 **9:05 AM**

Cooperative Radar Techniques: The Two-Step Detector

Max Scharrenbroich, Michael Zatman, QinetiQ North America

In this paper we analyze a two-step detection scheme for use in distributed sensor systems (e.g. statistical MIMO radar). The scheme arises when a data rate restriction forces each of the distributed systems to censor their detection statistics before sharing. We present the optimal Neyman-Pearson (NP) detection rule for the Swerling 2 target model, general expressions for the overall probability of false alarm and compare the performance of the optimal detector – which requires a priori knowledge of the SNR – with several practical detectors, showing how performance varies with the level of censoring.

WA3a-4 **9:30 AM**

Studying on Performance Behavior of the Compressive Sensing Measurements for Multiple Sensor System

Sangjun Park, Hwanchol Jang, Heung-No Lee, Gwangju Institute of Science and Technology

A performance analysis of Multiple-Sensor-System(MSS) on a compressive sensing(CS)[1] w.r.t. the per-sensor-measurements(PSM) is studied. In the proposed MSS, sensors make measurements using CS and the decoder jointly recover signals from them. We obtain the upper bound on the recovery failure probability for given K-sparse signals, derive the

relationship between PSM and the number of sensors(S) for the recovery. We examine the effect of SNR and S for the recovery. We use the concept of joint typicality proposed by Shannon[6]. We shows that PSM converges to the sparsity(K) as S increases for given K-sparse signals. Theoretical result is consistent with [3][4][5].

Track D. Signal Processing and Adaptive Systems

Session: WAb3 – Compressive Imaging and Detection

Chair: ***Aleksandar Dogandzic,*** *Iowa State University*

WA3b-1 10:15 AM

Multi-Static Radar Imaging via Bayesian Shrinkage

Raghu Raj, U.S. Naval Research Laboratory; Zachary Chance, David Love, Purdue University

We tackle the problem of multistatic radar image formation by simultaneously exploiting the sparsity and covariance structure of radar images measured by a GSM distribution of wavelet coefficients. In doing so we improve upon both the Fourier-based tomography and l1-based inversion approaches in terms of PSNR. Our formulation, under convex relaxation, reduces to a simultaneous sparse approximation problem which we implement via an efficient greedy OMP algorithm. Though we assume knowledge of the covariance structure of the source image, this provides a benchmark for subsequent relaxation of this assumption and its generalization to more complex probabilistic models of scene structure.

WA3b-2 10:40 AM

A Mask Iterative Hard Thresholding Algorithm for Sparse Image Reconstruction with Known Object Contour

Aleksandar Dogandzic, Kun Qiu, Iowa State University

We develop a mask iterative hard thresholding algorithm (mask IHT) for sparse image reconstruction with known object contour. The measurements follow an underdetermined linear model common in the compressive sampling literature. We assume that the contour of the object that we wish to reconstruct is known and that the signal outside the contour is zero. We first propose a constrained residual squared error minimization problem that incorporates both the geometric information (i.e. the knowledge of the object's contour) and the signal sparsity constraint. We then propose our mask IHT algorithm that aims at solving this minimization problem and guarantees monotonically non-increasing residual squared error. If we remove the hard thresholding operator, our mask IHT scheme becomes an iterative Landweber algorithm that imposes only the geometric contour constraint and yields the minimum-norm solution of the underlying linear system. We compare the proposed mask IHT and minimum-norm schemes with existing large-scale sparse signal reconstruction methods via numerical simulations and demonstrate that, by exploiting both the geometric contour information of the underlying image and the sparsity of its wavelet coefficients, we can reconstruct this image using a significantly smaller number of measurements than the existing methods.

WA3b-3 11:05 AM

Sensor Calibration Errors in Compressive Distributed-Aperture Radar Sensing

Peter Tuuk, Amy Sharma, Georgia Tech Research Institute

As unmanned aerial vehicles (UAVs) become more common, the desire for lightweight, low-power, inexpensive radar systems has increased. The impact of sensor calibration errors on a distributed-aperture radar utilizing compressed sensing techniques is explored herein. We developed a model to derive performance curves for detection of targets in range-angle- Doppler space using a number of single element radar transmitters/receivers versus the accuracy to which the locations of these sensors are known and the precision to which the system can be time-synchronized. Our results show that the compressed sensing process is not brittle with respect to modeling errors of this type.

WA3b-4 11:30 AM

Application of Compressive Sampling and Detection to Spectral Target Signatures

Lawrence E. Hoff, Hoff Engineering; David Buck, Brian T. Williams, SPAWAR System Center; Edward M. Winter, Technical Research Associates; Miaoli Yu, SAIC

Lawrence E. Hoff (1), Xiaoli Yu (2), David Buck (3), Brian Williams (3), Edwin M. Winter (4) (1) Hoff Engineering, San Diego, CA (2) SAIC (3) SPAWAR System Center, Pacific, San Diego, CA (4) Technical Research Associates, Honolulu, Hawaii Hyper-spectral sensors have proved useful for target recognition applications. However, when the numbers of spectral wavelengths and objects being tracked get large, there is a problem in storing, transmitting and processing the signatures. Recently, a great deal of progress has been made on data compression techniques known as Compressive Sampling. It is highly likely that future spectral tracking systems will incorporate compression along with the data acquisition. In this paper we examine algorithms for the reacquisition of targets of interest amongst other observed objects. The approach of this study was to evaluate spectral compression, recognition, and reconstruction algorithms on a simulated database of measured vehicle signatures.

Generalized likelihood ratio test and Spectral Angle Mapper recognition algorithms are evaluated on compressed signatures. Signature reconstruction is based upon the Kithonov method. The objective is to perform the reacquisition on the compressed data so that all compressed signature data does not have to be reconstructed, but only the signatures that are likely to be the target of interest. The ability to reacquire a target will depend upon the similarity of the target signatures and their signal to noise ratios. Using a database of 75 vehicle signatures, it was found that by using DCT to compress the spectra from 52 down to 25 bands, there was no loss over full spectrum processing and the target vehicles could be reacquired on the first try 95 per cent of the time.

Track C. Networks

Session: WAa4 – Cooperation & Relays

Chair: ***Emiliano Dall'Anese,*** *University of Minnesota*

WA4a-1 8:15 AM

The Gaussian Two-way Relay Channel With Wiretapper

Sungsoo Kim, The University of Texas at Austin; Won-Yong Shin, Harvard University; Koji Ishibashi, Shizuoka University

A Gaussian two-way relay wiretap channel (TRWC) is characterized, where two legitimate source nodes wish to exchange their messages through a relay in the presence of a separate eavesdropper, and then its secrecy capacity is derived. In the Gaussian TRWC, we propose an achievable coding scheme composed of superposed lattice codes with both structured and random codebook. A jamming strategy is further introduced at the two sources as well as at the relay, to maximize the achievable secrecy rate regions. In addition, assuming two sources with equal power, it is shown that the scheme asymptotically achieves within 1/2 bit from the cut-set bound based on the channel with no secrecy constraints, as the transmit power at the relay tends to infinity.

WA4a-2 8:40 AM

On-Demand Cooperation with Power Control: Protocol and Experimental Results

Christopher Hunter, Myuran Kanga, Lin Zhong, Ashutosh Sabharwal, Rice University

In cooperative communications, wireless devices pool their resources to increase overall reliability. However, devices that would normally be idle spend energy to help neighbors. This altruism is a source of much debate on the efficacy of cooperative communications. In this work, we present the Power-controlled Distributed On-demand Cooperation (P-DOC) protocol that employs cooperative relays in an energy efficient manner. P-DOC provides significant reduction in energy usage at cooperative relays in two key regimes: when relays are close to destination nodes and when they are far away. In this work, we describe P-DOC and evaluate the protocol in a variety of research domains: information theory, FPGA implementation, and network simulation.

WA4a-3 9:05 AM

A Practical Physical-Layer Network Coding Scheme for the Uplink of the Two-Way Relay Channel

Stephan Pfletschinger, Centre Tecnològic de Telecomunicacions de Catalunya (CTTC)

We consider the multiple-access phase of the two-way relay channel with the two-slot scheme and propose a practical decoding scheme which obtains the network coded packet. For low code rates, this scheme is found to perform better than lattice coding.

WA4a-4 9:30 AM

Empowering Full-Duplex Communication by Exploiting Directional Diversity

Evan Everett, Melissa Duarte, Rice University; Chris Dick, Xilinx, Inc.; Ashutosh Sabharwal, Rice University

The use of directional antennas in wireless networks has been widely studied with two main motivations: 1) decreasing interference and 2) improving power efficiency. We identify a third motivation for utilizing directional antennas: empowering full-duplex (FD) wireless communication. We evaluate FD operation in two scenarios that possess directional diversity: 1) multi-hop communication and 2) access-points with simultaneous uplink/downlink. It is shown that in both scenarios, using off-the-shelf WiFi directional antennas, FD operation significantly outperforms HD operation without requiring the FD terminals to use extra hardware for canceling the self-interference in the analog domain, as has been required in the previous work.

Session: WAb4 – Multiuser Information Theory

Chair: ***Aylin Yener,*** *Pennsylvania State University*

WA4b-1 10:15 AM

Intrinsic Multicast Region of Broadcast Channel

Mohammad (Amir) Khojastepour, NEC Laboratories America, Inc; Alireza Keshavarz-haddad, Shiraz University

We address the problem of multicasting individual and common information from a single transmitter (source) to multiple receivers(destinations). We consider the general case where a separate message could be intended for any subset of destinations. We call this problem multicasting in broadcast channel. The multicast achievable rate region of a N user broadcast channel is 2^N-1 dimensional region while the broadcast achievable rate region is a N dimensional region. Given a broadcast achievable rate tuple there is a set of rate tuple that are achievable for multicasting problem. The multicast rate region obtained by this \emph{generator} rate tuple consists of rate tuples that are not componentwise smaller than the generator rate tuple. For the general case of N users, we address the following questions (i) Given a generator rate tuple, what is the region achievable for any broadcast channel irrespective of its channel model, (ii) What is the largest achievable rate region, i.e., a region for which no point outside this region is universally achievable by any broadcast channel given a generator rate tuple. For a given generator rate tuple λ, the region which satisfies (i) and (ii) is called \emph{λ-intrinsic multicast region} due to the fact that it depends on an inherent structure of multicasting and not on the underlying broadcast channel model. In this paper, We derive an achievable multicast rate region for the general N-user broadcast channel which extend the known result for only $N=2$ and 3. We show that the obtained region is convex and hence there is no need for convex hall operation. We then show the maximal property of the proposed region under certain conditions and explicitly find the λ-intrinsic multicast region for those cases.

WA4b-2 10:40 AM

On the Gaussian Z-Interference Channel with Processing Energy Cost

Xi Liu, Elza Erkip, Polytechnic Institute of New York University

This work considers a Gaussian interference channel with processing energy cost, which explicitly takes into account the energy expended for processing when the transmitter is on. In the presence of processing energy overhead, transmitting all the time as in the conventional no-overhead case is no longer optimal. For a two-user Z-interference channel, conditions are first determined for the special case when interference does not incur any rate loss compared with the no-interference case. For the more general case, a joint transmission scheme is proposed to improve the sum rate and shown to be optimal when cross power gain a is large. When a is less than 1, the maximum achievable sum rate is further improved by allowing the interfered user to do power control.

WA4b-3 11:05 AM

On the Sum Capacity of the Y-Channel

Anas Chaaban, Aydin Sezgin, University of Ulm; Amir Salman Avestimehr, Cornell University

A model where three users communicate with each other via a relay is considered. Users do not receive other users' signals via a direct link, and thus the relay is essential for their communication. Each user wants to broadcast one message to each other user. The sum-capacity is studied, and upper bounds and lower bounds are given. If all nodes have the same power, the sum-capacity is characterized to within a gap of 5/2 bits or a factor of 3 for all values of channel coefficients. This gap is also shown to approach 3/2 bits as the transmit power increases.

WA4b-4 11:30 AM

Interference Channels with Source Cooperation in the Strong Cooperation Regime: Symmetric Capacity to within 2 bits/s/Hz with Dirty Paper Coding

Shuang (Echo) Yang, Daniela Tuninetti, University of Illinois, Chicago

The capacity region of the Gaussian interference channel with two source-destination pairs where the sources cooperate is not known. Prabakar and Viswanath showed that the sum-rate capacity can be achieved to within~18~bits/s/Hz by using a combination of superposition coding and zero-forcing. In this paper we focus on the {\em symmetric capacity} for sake of simplicity, that is, the maximum rate that the two sources can simultaneously achieve on a network with symmetric channel gains. We show that in the {\em strong cooperation regime} the ``binning-superposition'' achievable scheme of Yang and Tuninetti, implemented in a Gaussian channel by Dirty Paper Coding, achieves the symmetric capacity to within 2~bits/s/Hz. This means that the previously known 18~bits/s/Hz~gap for the sum-rate capacity can be reduced to 4~bits/s/Hz by using Dirty Paper Coding.

Track H. Speech, Image and Video Processing

Session: WAa5 – Signal Theory and Image Representation

Chair: ***P. P. Vaidyanathan,*** *California Institute of Technology*

WA5a-1 **8:15 AM**

Theory and Design of Unequal Order Analysis and Synthesis Filterbanks

Asha Vijayakumar, Anamitra Makur, Nanyang Technological University

Classical design of filterbanks results in equal order inverses, thus resulting in filterbanks with equal analysis and synthesis filter length. Literature shows that there does not exist a simple, systematic method to design a m^{th} order analysis and n^{th} order synthesis filterbank where $m \neq n$. In this work, we address the use of non diagonal matrix polynomial structure for the design of unequal order analysis and synthesis filters.

WA5a-2 **8:40 AM**

Learning Dictionaries for Local Sparse Coding in Image Classification

Jayaraman J. Thiagarajan, Andreas Spanias, Arizona State University

Low dimensional embedding of data lying on a manifold can be performed using locally linear modeling. By incorporating locality constraints, sparse coding can be adapted to modeling local regions of a manifold. This has been coupled with spatial pyramid matching to perform object recognition. In this paper, we propose an algorithm to learn dictionaries for computing local sparse codes of image patches. A modied distance metric is also proposed to identify the neighborhood for a data sample. Simulation results demonstrate that the proposed dictionary achieves improved classication accuracies when compared to using a K-means dictionary with standard image datasets.

WA5a-3 **9:05 AM**

Designing Thin Wavelet Filters

Youngmi Hur, Fang Zheng, The Johns Hopkins University

The tensor product wavelet filters--obtained from the univariate wavelet filters via the tensor product method--are the most popular wavelet filters in a multivariate setting. A drawback of the tensor product wavelet filters is that they are supported in dense regions. We discuss designing thin wavelet filters, and make a generalization to the recent development. The filters are thin in the sense that the average number of the non-zero coefficients in the analysis wavelet filters is very small. Unlike other non-tensor methods, the coset sum method keeps the benefits of the tensor product such as simplicity and fast algorithms.

WA5a-4 **9:30 AM**

Estimation of Signal Subspace-Constrained Inputs to Linear Systems

Alex Fink, Andreas Spanias, Arizona State University

Estimation of inputs to deterministic linear systems, based on noisy outputs, is of interest in applications ranging from target tracking to sound resynthesis. Considering prior information about inputs, such as the time-limited nature of striking a musical instrument, estimates may be made to meet known constraints. This paper presents a procedure to estimate the inputs, that are known a priori to reside in a signal subspace, in terms of a basis expansion. This method of estimating the inputs using a least-squares procedure, including recursive algorithms, is shown. Simulation results show that the estimates are improved when the constraints are known. Additionally, an application to sound resynthesis is presented.

Track H. Speech, Image and Video Processing

Session: WAb5 – Biometrics

Chair: ***Marios Savvides Savvides,*** *Carnegie Mellon University*

WA5b-1 **10:15 AM**

High Resolution Face Log from Surveillance Video

Thang Ba Dinh, Jongmoo Choi, Gérard Medioni, University of Southern California

We propose to acquire high resolution sequences of faces from multiple people using a pan-tilt-zoom (PTZ) network camera. This capability should prove helpful in forensic analysis of video sequences as frames containing faces are tagged, and within a frame, windows containing faces can be retrieved. Our system uses state-of-the-art modules: pedestrian detector, face detector, real-time tracker, and camera control. The tracker adaptively learns each target face, while the control automatically adjusts camera parameters to obtain a high resolution face image in the field of view. Validation is performed through extensive experiments in challenging indoor and outdoor conditions.

WA5b-2 **10:40 AM**

Quality Driven Face Recognition System for Surveillance Cameras

Saad Bedros, Yadhunandan U.S., Gurumurthy Swaminathan, Honeywell

With a drive for automated people identification and mining, a vast amount of research and techniques have been developed for acceptable face recognition under real scenarios. Most of the latest efforts are concentrated on high resolution still image face recognition under cooperative operational and environmental conditions. In order to take advantage of the current deployed video security infrastructure, there is an increasing demand for developing robust face recognition methodology that could be deployed for existing video surveillance cameras. We present an end to end system for high resolution megapixel cameras that detects, tracks faces from video, assess the quality of faces in the tracks then matches and fuses the information for multiple images from each track. With a high variation in resolution and quality of captured faces from different distances, a matching engine is developed based on a tunable Gabor decomposition, and a quality driven cascaded fusion of fisher classifiers for each Gabor scale.

WA5b-3 **11:05 AM**

Improved Iris Segmentation Based on Local Texture Statistics

Vishnu Naresh Boddeti, B.V.K. Vijaya Kumar, Krishnan Ramkumar, Carnegie Mellon University

We present an iris segmentation algorithm, which unlike previous iris segmentation is based on the local statistics of the texture region in the iris. Our segmentation algorithm builds upon the seminal work on active contours without edges, resulting in an iris segmentation algorithm that is tailored to segment poor quality iris images. We demonstrate the performance of our algorithm on the ICE and MBGC databases.

WA5b-4 **11:30 AM**

Radio Frequency Cardiopulmonary Waveform for Subject Identification

Marc O Griofa, Noninvasive Medical Technologies, Incorporated; Rebecca Blue, Orlando Health; Robert Friedman, Noninvasive Medical Technologies, Incorporated; Madhusudan Bhagavatula, Aaron Jaech, Siying Hu, Marios Savvides, Carnegie Mellon University

Radio Frequency Impedance Interrogation (RFII) measures hemodynamic function via resonance frequency coupling to a hydrophilic protein molecule and the resonant return signal phase change. The RFII device generates a cardiosynchronous waveform from the identification of blood movement in the time, frequency, and voltage domains. While the application of this technology to hemodynamic monitoring has demonstrated initial success, this small pilot study examined the use of RFII for subject identification by cardiosynchronous waveform signal analysis, which would allow confirmation of the identity of a subject in an operational setting. Preliminary results demonstrate 86% successful subject identification using the RFII cardiosynchronous waveform signature and simple pattern recognition classification, with as high as 100% identification with improvements to phase-shift recognition. Each individual appears to have a unique waveform morphology that is visually distinct from the other individuals in the data set. These results suggest that RFII may hold great potential as a biometric identifier and the rapid identification and authentication of subjects in the operational setting.

Track E. Array Signal Processing

Session: WAa6 – Computational Aspects in Array Processing

Chair: ***Christ Richmond,*** *MIT*

WA6a-1 **8:15 AM**

Fast Implementation of Sparse Iterative Covariance-Based Estimation for Array Processing

Qilin Zhang, Habti Abeida, Ming Xue, William Rowe, Jian Li, University of Florida

Fast implementations of the SParse Iterative Covariance-based Estimation (SPICE) algorithm are presented for source localization in passive sonar applications. SPICE is a robust, user parameter-free, high-resolution, iterative and globally convergent estimation algorithm for array processing. SPICE offers superior resolution and lower sidelobe levels for source localization at the cost of a higher computational complexity compared to the conventional delay-and-sum beamforming method. It is shown in this paper that the computational complexity of the SPICE algorithm can be mitigated by exploiting the Toeplitz structure of the array output covariance matrix using the Gohberg-Semencul factorization. The fast implementations for both the hydrophone uniform linear array (ULA) and the vector-sensor ULA scenarios are proposed and the computational gains are illustrated by numerical simulations.

WA6a-2 **8:40 AM**

Performance of Sample Covariance Based Capon Bearing Only Tracker

Christ Richmond, Robert Geddes, MIT Lincoln Laboratory; Ramis Movassagh, Alan Edelman, Massachusetts Institute of Technology

Bearing estimates input to a tracking algorithm require a concomitant measurement error to convey confidence. When Capon algorithm based bearing estimates are derived from low signal-to-noise ratio (SNR) data, the method of interval errors (MIE) provides a representation of measurement error improved over high SNR metrics like the Cramer-Rao bound or Taylor series. A corresponding improvement in overall tracker performance is had. These results have been demonstrated assuming MIE has perfect knowledge of the true data covariance. Herein this assumption is weakened to explore the potential performance of a practical implementation that must address the challenges of non-stationarity and finite sample effects. Comparisons with known non-linear smoothing techniques designed to reject outlier measurements are also explored.

WA6a-3 **9:05 AM**

Some Problems in the Analysis of Possibly Cyclostationary Data

David J. Thomson, Queen's University

Cyclostationary processes are encountered in fields ranging from climate to cognitive radio. When the cyclostationary period is unknown, or there are several periods, one must compute the Loeve spectrum to isolate the relevant period. Moreover, most processes encountered from natural sources contain emph{many} weak periodic, or almost periodic, components that cause spurious peaks in a Loeve two--frequency coherence estimate. This paper describes a process for estimating the Loeve spectrum by a SVD of the multitaper eigencoefficients that is both faster than the direct method and also has a lower false alarm rate than the naive approach. I also describe a multivariate version of the harmonic F--test for periodic components.

WA6a-4 **9:30 AM**

Extended Summary for Sidelobe Level Distribution for Linear and Planar Random Arrays with Arbitrary Element Distributions

Siddhartha Krishnamurthy, MIT Lincoln Laboratory / Harvard University; Daniel Bliss, MIT Lincoln Laboratory; Vahid Tarokh, Harvard University

The general form of the sidelobe level distribution is derived for linear and planar arrays with randomly located antenna elements with arbitrary element probability distributions. Two methods of calculating the sidelobe level distribution are presented. One involves sampling the beampattern. A more accurate method finds the number of times a beampattern crosses a certain level in an upward direction. Sidelobe level distributions using the number of upward-crossings are found for beampatterns with angle-dependent and angle-independent statistics. This evaluation of the probability of exceeding a given peak sidelobe is investigated as a function of the antenna array spatial position variance in the asymptotic limit of a large number of antennas. Examples are presented including a multi-input multi-output (MIMO) radar illustration.

Track E. Array Signal Processing

Session: WAb6 – Source Separation

Chair: ***Wing-Kin Ma,*** *Chinese University of Hong Kong*

WA6b-1 **10:15 AM**

Comparison of Varieties of Kalman Filtering Algorithms Applied to Single Microphone Blind Audio Source Separation

Siouar Bensaid, Dirk Slock, Eurecom

In this paper, we compare the adaptive EM-Kalman algorithm to the classic Extended Kalman Filter (EKF) within the mono-microphone blind source separation scheme. The separation is achieved by estimating the state as well as the unknown parameters of the state space model derived in this context. We also apply the Gaussian Second Order Extended Kalman Filter (SOEKF) to our bilinear case to perform better estimation of the desired parameters.

WA6b-2 **10:40 AM**

Insights into the Frequency Domain ICA/IVA Approach

Wenyi Zhang, UBS; Alireza Masnadi-Shirazi, Bhaskar D. Rao, University of California, San Diego

In this article, we examine and provide insights into the frequency domain ICA approach. We develop the concept of a dynamic random process to model the frequency domain source signals. It formalizes the concept of signals that are stationary in a frame but exhibit dynamics at the frame level. Frame dynamics is an important characteristics of these signals and this work

demonstrates its significant role in the success of the ICA methods in each frequency bin. We show that the independence between the marginal distributions of the source signals in each frequency bin is related to the independence of the frame dynamics of the time domain source signals. The frame dynamics also naturally leads to the marginal distribution of the source signal in each frequency bin being modeled by a Gaussian scale mixture (GSM). Concentrating on the bin-wise ICA methods, a significant contribution of the paper is to show that signals modeled using variance dependent GSM density can be separated using ICA even though they might be dependent on each other as long as the the frame dynamics of the source signals are different almost surely.

WA6b-3 11:05 AM

Blind Identification of Mixtures of Quasi-Stationary Sources Using a Khatri-Rao Subspace Approach

Ka-Kit Lee, Wing-Kin Ma, Chinese University of Hong Kong; Yi-Lin Chiou, Tsung-Han Chan, Chong-Yung Chi, National Tsing Hua University

This paper addresses the problem of blind identification of a linear instantaneous overdetermined mixture of quasistationary sources, using a new formulation based on Khatri-Rao (KR) subspace. A salient feature of this formulation is that it decomposes the blind identification problem into a number of per-source, structurally less complex, blind identification problems. We tackle the per-source problems by developing a specialized alternating projections (AP) algorithm. Remarkably, we prove that AP almost surely converges to a true mixing matrix column in its first iteration, assuming an ideal model condition. Simulation results show that the proposed algorithm yields competitive complexity and performance.

WA6b-4 11:30 AM

Improved Subspace Intersection Based on Signed URV Decomposition

Mu Zhou, Alle-Jan van der Veen, Delft University of Technology

Asynchronous co-channel interference mitigation is a tough problem for cellular systems, which greatly degrades the performance of multi-user receiver algorithms, especially blind source separation (BSS) algorithms when the interferences partially present in the time slot. Although ``codes'' based algorithms can more or less solve this problem, they require unique ``codes'' for each user and fail when the ``codes'' are corrupt by unknown effects, such as Doppler shift. In this paper, based on the fact that signals always present in observations but interferences not, we propose an improved subspace intersection (SI) based on the signed URV decomposition to find the interference-free subspace. By using the proposed SI, we propose a new preprocessing method for BSS algorithms. This method takes subspace intersections on the divided received data matrices and finds the desired subspace. Simulations show that our proposed method significantly improves the performance of BSS algorithms under asynchronous interferences.

Track G. Architecture and Implementation

Session: WAa7 – Multi-core/GPU Implementation

Chair: ***Jorn Jannick,*** *Lund University, Sweden*

WA7a-1 8:15 AM

GPGPU Accelerated Scalable Parallel Decoding of LDPC Codes

Guohui Wang, Michael Wu, Yang Sun, Joseph R. Cavallaro, Rice University

Low-density parity-check (LDPC) codes are widely adopted by the new emerging standards for wireless communication systems and storage applications due to their near-capacity error correcting performance. General-purpose graphics processing unit (GPGPU) is able to provide a low-cost and flexible software-based multi-core architecture, which enables the massively parallel high speed LDPC decoding. This paper proposes a GPGPU-based accelerator to speed up the decoding of LDPC codes. We explore the parallelism embedded in the check-node computation and variable-node computation and propose a parallel strategy of partitioning the decoding jobs among multi-processors in GPGPU. The contribution of this paper is two-fold: first, we propose a novel method to map the LDPC decoder onto GPGPU architecture, and an adaptive scheduling and performance-tuning algorithm to make our decoder implementation more flexible and scalable. Second, extensive study and experiments will be done to show the impact of the GPGPU's architecture to several key aspects such as the decoder reconfigurability, error-correcting performance, and throughput performance.

WA7a-2 **8:40 AM**

A High-Performance Area-Efficient AES Encipher on a Many-Core Platform

Bin Liu, Bevan Baas, University of California, Davis

This paper presents the design and software implementation of a high-performance area-efficient Advanced Encryption Standard (AES) encipher on a many-core platform. A preliminary encipher design is partitioned and mapped to an array of 70 small processors, and offers a throughput of 16.625 clock cycles per byte. The usage of instruction and data memory, and the workload of each processor are characterized for further optimization. Through workload balancing and processor fusion, the throughput of the encipher is improved by 43% to 9.5 clock cycles per byte, while the number of processors is reduced to 59, which is only 10.03 mm^2 in a 65 nm fine-grained many-core system. In comparison with other AES encipher implementations on state-of-art general purpose processors, our design has approximately 2.4-7 times higher throughput per area. Moreover, the presented encipher shows 4.3 times higher throughput than the implementations on TI DSP C6201 and 2.2 times higher throughput per area than GeForce 8800 GTX.

WA7a-3 **9:05 AM**

Parallel Implementation of the Wideband Coherent Signal-Subspace (CSS) Based DOA Algorithm on Single core, Multicore and GPU

Mohammad Wadood Majid, Mohsin Jamali, University of Toledo

Computation of Wideband Coherent Signal-Subspace (CSS) Based Direction of Arrival (DOA) has been parallelized and implemented on Multicore (Intel Nehalem Quad Core) and NVIDIA's GPU. This is in an effort to its use for real time applications. The CSS algorithm has been parallelized, partitioned, mapped and scheduled on Multi-Core/GPU. The parallel algorithm is developed in C# and a combination of C and CUDA for Multi-Core and GPU respectively. The algorithm has also been implemented on single core for comparison purposes. Wideband CSS algorithm is implemented assuming 16 and 4 sensors using Uniform Linear Array (ULA).

WA7a-4 **9:30 AM**

A Fine-Grained Parallel Implementation of a H.264/AVC Encoder on a 167-Processor Computational Platform

Zhibin Xiao, University of California, Davis; Stephen Le, Intel Corporation; Bevan Baas, University of California, Davis

The emerging many-core architecture provides a flexible solution for the rapid evolving multimedia applications demanding both high performance and high energy-efficiency. However, developing parallel multimedia applications that can efficiently harness and utilize many-core architectures is the key challenge for scalable computing. We contribute to this challenge by presenting a fully-parallel H.264/AVC baseline encoder on a 167-core asynchronous array of simple processors(AsAP) computation platform. By exploiting fine-grained data and task level parallelism in the algorithms, we partition and map the dataflow of the H.264/AVC encoder to an array of 115 small processors coupled with two shared memories and a hardware accelerator for motion estimation. The proposed parallel H.264/AVC encoder is capable of encoding video sequences with variable frame sizes. The encoder presented is capable of encoding CIF (352x288) video at 54 frames per second (fps) with 925 mW average power consumption by adjusting each processor to workload-based optimal clock frequencies and dual supply voltages with less than 1dB loss in resolution.

Track G. Architecture and Implementation

Session: WAb7 – Reconfigurable Architectures, Algorithms and Applications

Chair: ***Kenneth Jenkins,*** *Pennsylvania State University*

WA7b-1 **10:15 AM**

Designs of Angle-Rotation in Digital Frequency Synthesizer/Mixer Using Multi-Stage Architectures

Shen-Fu Hsiao, Cheng-Han Lee, Yen-Chun Cheng, National Sun Yat-sen University; Andrew Lee, University of California, Berkeley

The key operation of the quadrature digital frequency synthesizer/mixer (QDFS/M) in many communication systems is the rotation of an input vector in the complex plane. In this paper, we propose three multi-stage architectures for the design of the angle rotation in QDFS/M, targeting for different precision requirements. The rotation is decomposed into three sub-rotations, each implemented by ROM-based multiplication-addition, linear approximation, or CORDIC operations. The major design

consideration is to choose the proper architecture for a particular precision so that we can reduce the size of the required look-up table (LUT) and the bit widths of the corresponding arithmetic operations. Implementation results of various bit accuracies show that the best design choice depends on the desired precision.

WA7b-2 10:40 AM

Exploration of Sign Precomputation-Based CORDIC in Reconfigurable Systems

Scott Miller, Dian Ross, Mihai Sima, Michael McGuire, University of Victoria

Presented is an analysis of Field-Programmable Gate Array (FPGA) implementations of standard CORDIC with sign precomputation. Sign precomputation has been proposed as a higher speed improvement to the standard serial CORDIC algorithm, but little analysis exists on reconfigurable implementations. This work shows that compared with full-custom silicon implementations of CORDIC with sign precomputation, FPGAs see reduced benefits in terms of propagation delay improvement at the expense of increased FPGA resource utilization. Nevertheless, when delay is of paramount importance for an application, sign precomputation is shown to reduce delay by up to 14% when implemented on FPGAs.

WA7b-3 11:05 AM

A Reduced Routing Network Architecture for Partial Parallel LDPC Decoders

Houshmand Shirani-Mehr, University of California, Davis; Tinoosh Mohsenin, University of Maryland, Baltimore County; Bevan Baas, University of California, Davis

A novel partial parallel decoding scheme based on the matrix structure of LDPC codes proposed in IEEE 802.15.3c and IEEE 802.11ad standards is presented that significantly simplifies the routing network of the decoder, and the class of parity-check matrices for which the method can be used is defined. The proposed method results in almost complete elimination of logic gates on the routing network, which results in improvements in area, speed and power, with an identical error correction performance to conventional partial-parallel decoders. A decoder for the (672,588) LDPC code adopted in IEEE 802.15.3c is implemented in a 65 nm CMOS technology including Place & Route with both proposed permutational decoder, and conventional partial-parallel architecture. The proposed permutational LDPC decoder operates at 238 MHz and delivers a throughput of 8.01 Gbps with 5 decoding iterations per block. The proposed permutational decoder has a throughput 26% higher and is approximately 20% smaller than the original partial-parallel decoder.

WA7b-4 11:30 AM

Automatic FFT Code Generation for FPGA with High Flexibility and Human Readability

John O'Sullivan, Institute for System Level Integration / Steepest Ascent Ltd.; Stephan Weiss, University of Strathclyde; Garrey Rice, Steepest Ascent Ltd.

This paper describes a fast Fourier transform (FFT) core designed to work with code generation tools to create an optimised, continuous throughput FFT core for a power of 2 length. The FFT core designed to be human readable, is not vendor specific and is available in both Verilog and VHDL. In-place and MDC (Multipath Delay Commutator) architectures are selectable and the relative merits are discussed. The core is to be included in a Hardware Description Language (HDL) generation and DSP synthesis tool allowing a bit true version of the core to be used in high level system design.

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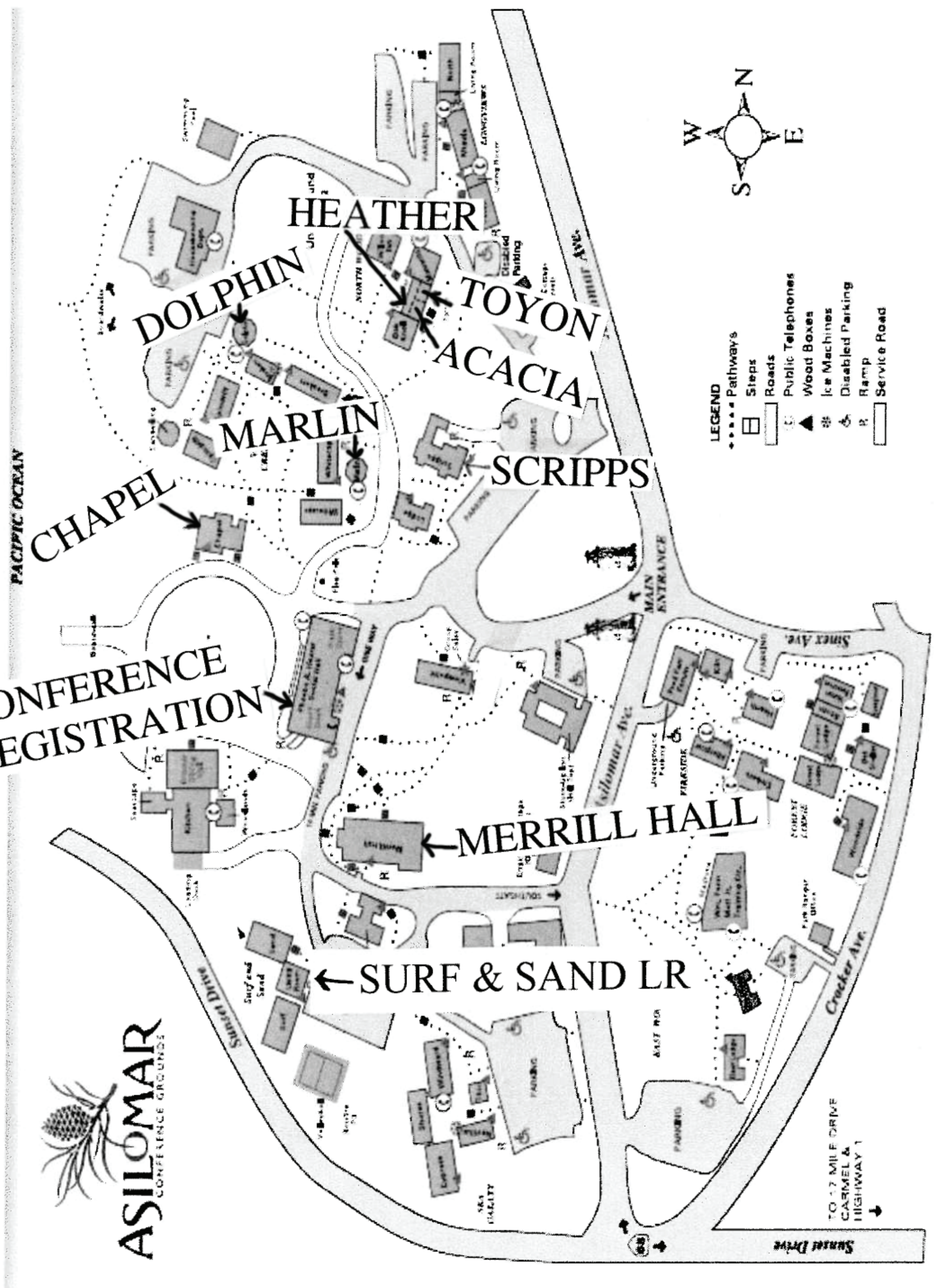

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