Plenary Talks

Wednesday, Dec. 14, 9:00–10:00 P. R. Kumar. Networked cyberphysical systems.

Abstract: Networked computers controlling distributed physical systems represent the next phase of development from several different technological points of view. For the networking community, they can be seen as the next logical step beyond sensor networks, since actuation is also supported. For the real time community, it represents an advanced into networked systems. For the control community, they can be regarded as the third generation of control, coming after the first two generations of analog control and digital control. Such networked cyberphysical systems are expected to be increasingly important as we enter the large scale system building era of the twenty-first century. We present both an account of several foundational research topics that underlie this area, as well as examples of system building possibilities. As research topics of interest for these next generation systems, we survey issues in data fusion, real-time communication, clock synchronization, security, middleware, hybrid systems and proofs of correctness.

Wednesday, Dec. 14, 13:00–14:00 Jeffrey Krolik. MIMO situational awareness radar.

Abstract: This work addresses the problem of radar surveillance in environments where multipath and non-line-of-sight propagation limit the effectiveness of conventional systems. Complex propagation is prevalent in applications as diverse as automotive radar, indoor radar, and over-the-horizon radar. For ground-moving target indication (GMTI) radar, multipath propagation can result in target masking by Doppler-spread ground clutter which cannot be mitigated by conventional space-time adaptive processing. For synthetic aperture radar (SAR), non-line-of-sight propagation can cause troubling image artifacts. In this paper, we discuss how MIMO space-time processing can be used to improve both GMTI and SAR situational awareness from a moving vehicle. The unique MIMO radar capability of discriminating both radar signal direction-of-arrival and direction-of-departure as a function of time delay is shown to be critical for situational awareness in complex environments. In addition to simulation results, a real-time testbed radar demonstration will be presented.

Thursday, Dec. 15, 9:00–10:00 José M. F. Moura. When is distributed as good as centralized?

Abstract: From networks of social agents, interacting locally but aspiring to global understanding, to physical networked systems like the power grid, where distributed SCADAs could become candidates to replace centralized supervisory control and data acquisition systems, we can ask if and when a distributed algorithm offers performance guarantees similar to those of a centralized solution. We consider consensus+innovations algorithms that combine local cooperation among agents (in-network processing) with local exchanges with the external world (sensing). To understand these mixed scale algorithms we establish their path behavior and the exponential decay rates of the probability of rare events (large deviations principle.) These algorithms need careful design, in particular, how to weigh the consensus and innovations terms. We illustrate relevant tradeoffs among network parameters (e.g., rate of diffusion, communication and sensing signal-to-noise ratios,) and determine that, under broad conditions, yes, distributed can be as good as centralized.

Thursday, Dec. 15, 13:00–14:00 Robert W. Heath Jr. The limited feedback revolution in wireless communication.

Abstract: Wireless communication systems have improved efficiency in several dimensions in the past decade. One prominent change is the sweeping incorporation of multiple antennas, at both the transmitter and receiver, to achieve higher capacity, better quality, and resilience to interference through new modes of operation. A corresponding advance, resulting from increasing flexibility in the transmitter configuration, is algorithms that adapt the transmit strategy to the dynamic propagation environment. The concept of limited feedback lies at the heart of these two fundamental changes in wireless design. Limited feedback is a methodology for obtaining and exploiting propagation channel state information at the transmitter. It uses a finite rate feedback control channel to convey quantized observations of the channel from the receiver to the transmitter. Limited feedback allows the transmitter to adjust how antennas are configured and change other parameters like the transmission rate to maximize performance. This presentation reviews several breakthroughs in limited feedback multiple antenna wireless communication. The connection between limited feedback and quantization on the Grassmann manifold is explained. Then, a new approach for adaptive high resolution limited feedback beamforming is revealed. It leverages temporal correlation in the channel through a new predictive coding framework that reduces feedback rates and/or increases effective resolution. The application of this new framework specifically for high resolution limited feedback interference alignment in interference channels is discussed.

Friday, Dec. 16, 9:00–10:00 Juan F. Arratia. Educational and research activities at the student research development center of the Ana G. Mendez University System.

Abstract: The Ana G. Mendez University System (AGMUS), the second university system in Puerto Rico, includes three main campuses- Universidad Metropolitana (UMET), Universidad del Turabo (UT) and Universidad del Este (UNE), sixteen off-campus centers (three in Florida) serving underrepresented minority students, a PBS Television Station, and a recently started Universidad Virtual. The total AGMUS enrollment is 42,000 students, 3,726 full-time and adjunct faculty, multiple, science, technology, engineering, and mathematics (STEM) BSD and graduate programs.
UMET and The Arecibo Observatory are developing the Puerto Rico Photonics Institute at the facilities of the Barceloneta Scientific Research Park in northern Puerto Rico. This institute is partnering with Honeywell, the Aguadilla facility, in the development of laser technology for GPS Instrumentation and laser applications in navigation systems. Honeywell is negotiating the implementation of an MS in Aerospace Engineering with AGMUS. The National Science Foundation (NSF) awarded 2.3 million to UMET for the construction of an Advanced Modular Incoherent Scatter Radar (AMISR) at the geomagnetic conjugate point of the Arecibo Observatory in La Plata, Argentina. The Principal Investigator of the project is working with Stanford Research Institute (SRI) for the construction, transportation and installation of the radar in Argentina. The main objective of this radar is to study the plasma flow at the ionosphere in conjunction with a heater at the Arecibo Observatory. The AMISR facility in Argentina will be operated in partnership with Universidad de La Plata, the Arecibo Observatory and AGMUS, impacting undergraduate, graduate students, faculty and scientists from Puerto Rico, Argentina, and the US scientific community.
This presentation will address the history of the transformation of the AGMUS institutions from liberal art colleges to a leading undergraduate research organization in Puerto Rico by describing the outcome of each grant sponsored by the NSF.

Friday, Dec. 16, 13:00–14:00 Robert Calderbank. Faster than Nyquist but slower than Tropp.

Abstract: The sampling rate of analog-to-digital converters is severely limited by underlying technological constraints. Recently, Tropp *et al.* proposed a new architecture, called a random demodulator, that attempts to overcome this limitation by sampling sparse, band limited signals at a rate much lower than the Nyquist rate. An integral part of this architecture is a random bi-polar modulating waveform that changes polarity at the Nyquist rate of the input signal. Technological constraints also limit how fast such a waveform can change polarity.
We propose an extension of the random demodulator that uses a run-length limited (RLL) modulating waveform, and which we call a constrained random demodulator (CRD). The RLL modulating waveform changes polarity at a slower rate. We demonstrate that a CRD enjoys theoretical guarantees similar to the RD and that these guarantees are directly related to the power spectrum of the modulating waveform. Further, we show that the relationship between the placement of energy in the spectrum of the input signal and the placement of energy in the power spectrum of the modulating waveform has a major effect on the reconstruction performance of signals sampled by a CRD.

MIMO Radar, Wednesday, Dec. 14, 10–12

10:00 Daniel Fuhrmann. MIMO radar signal processing for distributed phased arrays.

Abstract: We explore various transmit signaling and receive signal processing strategies for a MIMO radar scenario involving multiple phased arrays that could be widely distributed. The assumptions are that within a phased array, there is a fixed rigid geometry and perfect phased synchronization, and there is a single look at the target. In contrast, between phased arrays there is imperfect phase synchronization and multiple views of the target. We show how the challenge of maintaining signal phase coherence on target is made difficult with increased aperture separation, and question whether or not this is even desirable in light of multiple-scatterer target models and imperfect knowledge of target location.

10:20 Marie Ström and Mats Viberg. Low PAPR waveform synthesis with application to wideband MIMO radar.

Abstract: This paper considers the problem of waveform synthesis given a desired power spectrum. The properties of the designed waveforms are such that the overall system performance is increased. The metric used to evaluate the optimality of the synthesized time domain signals is the peak-to-average power ratio (PAPR). We discuss how to synthesize waveforms using the technique of partial transmit sequence (PTS). The key point is that the gradient can explicitly be derived from the objective function. Furthermore, the result is extended by allowing the power spectrum to deviate from its original shape, yielding a further reduction in the PAPR. The method is applied to derived power spectra for wideband multiple-input-multiple-output (MIMO) radar. It is shown that the proposed technique can achieve optimal or near optimal performance with PAPR below 0.5 dB.

10:40 Marie Ström, Mats Viberg, and Kent Falk. Transmit and receive filter optimization for wideband MIMO radar.

Abstract: In this paper, we discuss the possibility to suppress interference for wideband multiple-input-multiple-output (MIMO) radar, using only the temporal properties of the signals. The idea is to use tunable filters each connected to a wideband waveform generator, and to derive the optimal power spectral density (PSD) of the resulting signals in a known environment. The metric used to evaluate the enhancement in the system performance is the signal-to-noise and interference ratio (SNIR), from which the optimal transmit and receive filter properties are derived. We discuss two optimization approaches: one alter- nating and one joint algorithm. Each method is separated into two cases: for a total power constraint and for an individual power constraint on the transmit filters, respectively. Numerical validation illustrates the possibility to suppress the interference in the temporal domain, without actually forming a spatial null in the direction of the interference.

11:00 Sandeep Gogineni and Arye Nehorai. Adaptive waveform design for colocated MIMO radar using sparse modeling.

Abstract: We consider the problem of multiple target estimation using a colocated Multiple Input Multiple Output (MIMO) radar system. We employ sparse modeling to estimate the unknown target parameters (delay, Doppler) using a MIMO radar system that transmits frequency-hopping waveforms. Further, we use the estimates of the target RCS values to adaptively design the amplitudes of the transmit waveforms during each hopping interval. We demonstrate the performance improvement using numerical examples.

11:20 Sandeep Gogineni and Arye Nehorai. Polarimetric MIMO radar target detection using game theory.

Abstract: Polarimetric radar systems allow the flexibility of transmitting arbitrarily polarized waveforms that match the scattering profiles of the target. Since different types of targets have varying profiles, the advantages of a polarimetric radar system can fully be exploited only when the type of target is accurately estimated. However, accurate estimation requires a significant amount of training data, which can be expensive. We propose a polarimetric design scheme for distributed Multiple Input Multiple Output (MIMO) radar target detection. We formulate the selection of transmit polarizations using a game theoretic framework by examining the impact of all possible transmit schemes on the detection performance with different available target profiles. This approach does not require training data, and we show a significant performance improvement due to the polarimetric design.

11:40 Junhyeong Bae and Nathan A Goodman. Widely separated MIMO radar with adaptive waveform for target classification.

Abstract: In prior work, we have shown the advantage of adaptive waveforms for monostatic radar target recognition performance. In this paper, we extend our approach to the widely separated multi-input multi-output (MIMO) radar scenario. MIMO radar exploits a diversity of radar waveforms and target scattering to improve radar performance. We present an iterative information-based waveform design method that results in waveforms having narrow, disjoint bands so as not to interfere with each other. Applying a constant modulus constraint causes spectral spreading, but we study the impact of this spreading and find that the performance loss is minimal.

Signal Processing Applied to Financial Engineering Problems, Wednesday, Dec. 14, 10–12

10:00 Francisco Rubio, Xavier Mestre, and Daniel P. Palomar. Asymptotic analysis and consistent estimation of high-dimensional Markowitz portfolios.

Abstract: We study the consistency of large-dimensional mean-variance portfolios that estimated on the basis of weighted sampling and shrinkage. In an asymptotic setting where the number of assets remains comparable in magnitude to the sample size, we provide a characterization of the estimation risk by providing deterministic equivalents of the portfolio out-of-sample performance in terms of the underlying investment scenario. The previous estimates represent a means of quantifying the amount of risk underestimation and return overestimation of improved portfolio constructions beyond standard ones. Well-known for the latter, if not corrected, these deviations lead to inaccurate and overly optimistic Sharpe-based investment decisions. Our results are based on recent contributions in the field of random matrix theory. Along with the asymptotic analysis, the analytical framework allows us to find bias corrections improving on the achieved out-of-sample performance of typical portfolio constructions.

10:20 Emmanuelle Jay, Patrick Duvaut, Serge Darolles, and Christian Gouriéroux. l^q-regularization of the Kalman filter for exogenous outlier removal: Application to hedge funds analysis.

Abstract: This paper presents a simple and efficient exogenous outlier detection estimation algorithm introduced in a regularized version of the Kalman Filter (KF). Exogenous outliers that may occur in the observations are considered as an additional stochastic impulse process in the KF observation equation that requires a regularization of the innovation in the KF recursive equations. Regularizing with a l1- or l2-norm needs to determine the value of the regularization parameter. Since the KF innovation error is assumed to be Gaussian we propose to first detect the possible occurrence of an exogenous impulsive spike and then to estimate its amplitude using an adapted value of the regularization parameter. The algorithm is first validated on synthetic data and then applied to a concrete financial case that deals with the analysis of hedge fund returns. The proposed algorithm can detect anomalies frequently observed in hedge returns such as illiquidity issues.

10:40 Mustafa Torun and Ali Akansu. On Epps effect and rebalancing of hedged portfolio in multiple frequencies.

Abstract: Correlations of financial asset returns play a central role in designing investment portfolios by using Markowitz's modern portfolio theory (MPT). Correlations are calculated from asset prices that happen at various trading time intervals. Therefore, trading frequency dictates correlation values. This phenomenon is called the Epps effect in finance. We present variations of correlations as a function of trading frequency to quantify Epps effect. The results reiterate that portfolio rebalancing, particularly in multiple trading frequencies, requires good estimation of correlations in order to deliver reliable hedging.

11:00 Ilya Pollak. Weight shrinkage for portfolio optimization.

Abstract: The paper starts by reviewing the basics of the modern portfolio theory and its very well known drawbacks. After a brief overview of the existing literature that attempts to address these drawbacks, a novel portfolio mixing method is proposed. The method is then illustrated using US stock market data, and is shown to outperform both portfolios that it combines in a statistically significant way. Several avenues of further research are summarized to conclude the paper.

11:20 Gareth Peters, Ben Lasscock, and Kannan Balakrishnan. Rank estimation in cointegrated vector auto-regression models via automated trans-dimensional Markov chain Monte Carlo.

Abstract: This paper develops a novel automated Transdimensional Markov chain Monte Carlo sampling methodology for Bayesian Cointegrated Vector Auto Regression models. In automating the rank and cointegration vector estimation in CVAR models we solve an important problem in algorithmic trading model development for cointegrated price series. The automation of both the within model subspace sampling for the cointegration vectors directions and the between model rank estimation Markov chain proposal is achieved by developing a global matrix variate proposal centered on the MLE and with covariance given by the observed Fisher Information matrix. To obtain this in the matrix variate CVAR setting under an error correction formulation involved a non trivial derivation of the observed Fisher information matrix for each model subspaces unconstrained cointegration vector components, conditional on the components of the long run multiplier matrix which are constrained for identifiability. We then apply this algorithm to both synthetic data as well as real futures data on U.S. treasury notes, bonds and US equity indexes. In each analysis, we compare the estimated rank based on the estimated posterior model probabilities for the rank to simple Bayes Factor estimated posterior rank probabilities and the classical hypothesis test of the rank based on the trace statistic of the long run multiplier matrix of Johansen.

Advances in Geographical Positioning, Wednesday, Dec. 14, 14–16

14:00 Jonathan Bosse, Anne Ferreol, and Pascal Larzabal. A glance on geographical positioning.

Abstract: Geographical positioning have attracted considerable interest during the last decades due to the potential of such an information for civilian applications as well as for military applications. This paper recalls the main issues and solutions in some localization problems depending on the experimental context. It offers a brief review and evokes recent directions in which studies are led. This paper is an introduction paper for the special session "Advances in geographical positionning" in CAMSAP 2011. It provides a common framework for the research papers which will be presented in the session.

14:20 Lamberto Inza, Jerome I. Mars, Jean-Philippe Metaxian, Gareth O'Brien, and Orlando Macedo. Localization with multicomponent seismic array.

Abstract: Seismo-volcano source localization is essential to improve our understanding volcano systems. The lack of clear seismic wave phases prohibits the use of classical location methods. Seismic antennas composed of one-component (1C) seismometers provide a good estimate of the back-azimuth of the wavefield. The depth estimation, on the other hand, is difficult or impossible to determine. In order to determine the source location parameters (back-azimuth and depth), we extend the 1C seismic antenna approach to 3Cs. This communication discusses a high-resolution location method using a 3C array survey (3C-MUSIC algorithm) with data from two seismic antennas installed on an andesitic volcano in Peru (Ubinas volcano). After introducing the 3C array theory, we evaluate the robustness of the location method on a full wavefield 3D synthetic dataset generated using a digital elevation model of Ubinas volcano and an homogeneous velocity model. Results show that the back-azimuth determined using the 3C array has a smaller error than a 1C array. Only the 3C method allows the recovery of the source depths. Finally, we applied the 3C approach to two seismic events recorded in 2009. Therefore, extending 1C arrays to 3C arrays in volcano monitoring allows a more accurate determination of the source epicenter and now an estimate for the depth.

14:40 Joseph S. Picard and Anthony Weiss. Time-delay and Doppler-shift based geolocation in the presence of outliers.

Abstract: We address the problem of locating a stationary transmitter using receivers embedded in fast moving platforms. It is required to estimate the emitter location using time-delay and Doppler-shift measurements realized by the receivers at successive locations along their trajectories. Most publications consider small error measurements only, and overlook the possible presence of outliers in the set of time-delay and Doppler-shift measurements. In this work we discuss localization in the presence of outliers, where several measurements are severely corrupted while sufficient other measurements are reasonably precise. Following convexity and sparsity principles, we propose a localization algorithm with robustness against outliers.

15:00 Claus Pedersen, Troels Pedersen, and Bernard Henri Fleury. Exploiting network topology information to mitigate ambiguities in VMP localization.

Abstract: We investigate an extension to the probabilistic model of a wireless sensor network (WSN) in the variational message passing localization algorithm. This extension exploits network topology information to mitigate ambiguities in WSN localization schemes. We verify and compare the performance of the direct and the 2-hop position relaying VMP localization algorithms by Monte Carlo simulations. The results show that utilizing position information from sensors with which there is no direct connection improves the position estimates for sensors directly connected to few neighbour sensors.

15:20 Marek Schikora, Marc Oispuu, Wolfgang Koch, and Daniel Cremers. Multiple source localization based on biased bearings using the intensity filter — Approach and experimental results.

Abstract: This paper investigates the three-dimensional localization problem for multiple emitters using a realistic airborne array sensor. In order to achieve improved results systematic and statistical direction finding errors are considered in a unified algorithm. The task is solved using a sequential Monte Carlo implementation of the intensity filter (iFilter). In this paper, we compare two localization approaches without and with the consideration of systematic bearing errors and verify them with an experimental data set. The comparison of both approaches reveals that the bias consideration offers a superior performance.

Through-the-Wall Imaging, Wednesday, Dec. 14, 14–16

14:00 Peter Weichman. Physics-based EM models in support of through-wall microwave imaging.

Abstract: In this paper I review some recent physics-based modeling approaches in support of microwave through-wall building tomography. Building layout estimation is a nonlinear inverse problem with a large number of degrees of freedom (geometry, location, and scattering properties of major building elements, such as walls, floors, and ceilings, plus many other smaller elements such as windows, doorways, and stairways). I will describe the microwave propagation physics, involving multiple reflection, transmission, and diffraction events, which must be accounted for in the creation of a high fidelity, numerically efficient forward model. Through sensitivity tests and comparison with experimental data, these models allow one to quantify some of the fundamental limits that the signal complexity places on building interior estimation.

14:20 Emre Ertin, Randy Moses, and Robert Burkholder. Autofocus for coherent through-the-wall imaging with multiple antenna arrays.

Abstract: We consider the problem of coherent through-the-wall imaging with spatially distributed antenna arrays. A compact antenna array with wide bandwidth can be used to provide snapshots of a scene at high range resolution. The physical size of the antenna aperture limits the cross-range resolution of the array. Multiple arrays at spatially diverse locations can increase cross-range resolution, however coherent operation requires precise knowledge of the array locations and distortions caused by the wall propagation. We present a method for spatially-variant autofocus for distributed arrays by maximizing the coherence between the images provided by the individual arrays interrogating a common scene. Examples with measured data illustrate the effectiveness of the distributed array approach to coherent through-the-wall imaging.

14:40 Michael Leigsnering, Abdelhak M. Zoubir, and Mounir Ghogho. Fast wideband near-field imaging with URAs applied to urban sensing.

Abstract: High resolution wideband near-field imaging requires wideband signals and large array apertures. Hence, a large amount of data needs to be processed in the image formation step. The computational load of the standard delay and sum beamformer stems from the calculation of the focus delays and the evaluation of the sums over the measurements. We propose an approach tackling the problem of calculating the focus delays. Provided a uniform rectangular array (URA) is used, the image can be evaluated on a well tailored discrete grid such that most focus delays are redundant. Now by calculating only the non-redundant values we can reduce the numerical complexity significantly. The above approach is combined with fast beamforming based on the non-equispaced fast Fourier transform (NFFT). We demonstrate the good performance with experimental results from a through-the-wall radar imaging system.

15:00 Marija Nikolic, Arye Nehorai, and Antonije Djordjevic. Sparse through-the-wall imaging.

Abstract: We consider electromagnetic imaging of targets hidden behind dielectric walls using sparse regularization. We assume that the targets can be suitably represented by a set of unknown filament currents as in the equivalent-source method. We combine the surface-equivalence theorem and the ray tracing to obtain a linear measurement model. We investigate the efficiency of the proposed method in reconstructing both dielectric and metallic targets.

Advances in the Theory and Practice of Computationally Intensive Methods for Statistical Signal Processing, Thursday, Dec. 15, 10–12

10:00 Katrin Achutegui and Joaquin Míguez. A parallel resampling scheme and its application to distributed particle filtering in wireless networks.

Abstract: We address the design of a particle filter (PF) that can be implemented in a distributed manner over a network of wireless sensor nodes, each of them collecting their own local data. This is a problem that has received considerable attention lately and several methods based on consensus, the transmission of likelihood information, the truncation and/or the quantization of data have been proposed. However, all existing schemes suffer from limitations related either to the amount of required communications among the nodes or the accuracy of the filter outputs. In this work we propose a novel distributed PF that is built around the distributed resampling with non-proportional allocation (DRNA) algorithm. This scheme guarantees the properness of the particle approximations produced by the filter and has been shown to be both efficient and accurate when compared with centralized PFs. The standard DRNA technique, however, places stringent demands on the communications among nodes that turn out impractical for a typical wireless sensor network (WSN). In this paper we investigate how to reduce this communication load by using (i) a random model for the spread of data over the WSN and (ii) methods that enable the out-of-sequence processing of sensor observations. A simple numerical illustration of the performance of the new algorithm compared with a centralized PF is provided.

10:20 Li Geng and Petar M. Djurić. Non-centralized target tracking in networks of directional sensors: Further advances.

Abstract: Directional sensors detect targets within a range and a predefined direction. In this paper, we assume that directional sensors are deployed in a sensor field, where at each node there are four collocated directional sensors providing a coverage of 36o degrees. We extend results of some of our previous work on this subject and study the effects of different network parameters on the performance of the proposed methods. We also extend the methods so that they can track more than one target simultaneously moving in the sensor field.

10:40 Pau Closas and Monica F. Bugallo. Iterated multiple particle filtering.

Abstract: In the literature, there are claims stating that particle filters cannot be used for complex systems because their random measures degenerate to single particles. While this is true for standard implementation of these filters, it does not hold true for alternative approaches. A new methodology based on the principle of divide and conquer has already been proposed, where the collapse of traditional particle filtering is avoided by setting an interconnected network of filters, each of them working on lower dimensional spaces. In this paper we propose an enhanced version of multiple particle filtering, which uses tools of game theory for improved performance of the overall system. Computer simulations show that the new approach outperforms both standard and multiple particle filters.

11:00 Silvia Paris, David Mary, and André Ferrari. PDR and LRMAP detection tests applied to massive hyperspectral data.

Abstract: Recent works showed that two composite detection tests based on Maximum A Posteriori (MAP) estimates can be more powerful than the Generalized Likelihood Ratio (GLR) in the case of sparse parameters. These tests are the Posterior Density Ratio (PDR), which computes the ratio of the a posteriori distribution under each hypothesis, and the LRMAP, where the MAP replaces the Maximum Likelihood estimate. We propose here a compared analysis of the two MAP-based tests performances. The implementation details of these tests are then analyzed in the framework of massive hyperspectral data which will be acquired by the MUSE integral field spectrograph. We finally improve the detection strategy proposed in [8] by better exploiting the spatial dependencies existing in the data cube.

11:20 Henri Lantéri, Céline Theys, and Cédric Richard. Nonnegative matrix factorization with regularization and sparsity-enforcing terms.

Abstract: The aim of this paper is to present several multiplicative algorithms for nonnegative matrix factorization. We show how to obtain such algorithms in the case where non-negativity and flux conservation constraints are imposed, and how to regularize such problems by introducing smoothness or sparsity properties. Application to hyperspectral imagery is finally considered.

11:40 Celine Quinsac, Nicolas Dobigeon, Adrian Basarab, Denis Kouame, and Jean-Yves Tourneret. Bayesian compressed sensing in ultrasound imaging.

Abstract: Following our previous study on compressed sensing for ultrasound imaging, this paper proposes to exploit the image sparsity in the frequency domain within a Bayesian approach. A Bernoulli-Gaussian prior is assigned to the Fourier transform of the ultrasound image in order to enforce sparsity and to reconstruct the image via Bayesian compressed sensing. In addition, the Bayesian approach allows one to estimate the image sparsity level in the spectral domain, a significant parameter in the l1 constrained minimization problem linked to compressed sensing. Results presented here, on a simulated ultrasound image and an in vivo image of a human thyroid gland, show a reconstruction as good as those from classical compressed sensing, from half of spatial samples, while estimating the sparsity level during reconstruction.

Estimation, Learning, and Optimization for the Smart Power Grid, Thursday, Dec. 15, 10–12

10:00 Di Wu, Chengrui Cai, and Dionysios Aliprantis. Potential impacts of aggregator-controlled plug-in electric vehicles on distribution systems.

Abstract: This paper presents potential impacts on distribution systems from light-duty plug-in electric vehicles (PEVs), when these are under the control of aggregators who desire to maximize their energy trading-related profits. The electric load characteristics of light-duty PEVs are developed using the travel pattern from the 2009 National Household Travel Survey. This PEV load is added to the existing non-PEV load within one of the prototypical feeders developed by the Pacific Northwest National Laboratory.

10:20 Seung-Jun Kim and Georgios B. Giannakis. Efficient and scalable demand response for the smart power grid.

Abstract: A demand response setup is considered entailing a set of appliances with deferrable and non-interruptible tasks. A mixed-integer linear programming model for scheduling the operational periods and power levels of the appliances is formulated in response to known dynamic pricing information with the objective of minimizing the total electricity cost and consumer dissatisfaction. A scalable algorithm yielding a near-optimal solution is developed by enforcing a separable structure, and using Lagrangian relaxation. Thus, the original problem is decomposed to per-appliance subproblems, which can be solved exactly based on dynamic programming. The proximal bundle method is employed to obtain a solution to the convexified version, which helps recovery of a primal feasible solution. Numerical tests validate the proposed approach.

10:40 Liyan Jia, Zhe Yu, Mary Murphy-Hoye, Annabelle Pratt, Ellen Piccioli, and Lang Tong. Multi-scale stochastic optimization for home energy management.

Abstract: The problem of optimal control of appliances for Home Energy Management (HEM) is considered. An HEM device interfaces with an energy aggregator through real time pricing and a load profile that specifies the hourly maximum consumption level. A multi-scale multi-stage stochastic optimization framework is proposed for the control of the Heating, Ventilation, and Air Conditioning (HVAC) unit, the charging of Plug-in Hybrid Electric Vehicle (PHEV), and the scheduling of deferrable load such as washer/dryer operations. Formulated as a constrained stochastic optimization that incorporates thermal dynamics, temperature measurements, and the real time pricing signal, a model predictive control algorithm is proposed that minimizes customer's discomfort level subject to cost and peak power constraints.

11:00 Bei Yan, Hanoch Lev-Ari, and Aleksandar Stanković. Multi-sensor networked estimation in electric power grids.

Abstract: Progress in communication technology has opened up the possibility of large scale control system in which the control task is distributed among several processors, sensors, estimators and controllers interconnected via communication channels. Such control systems may be distributed over long distances and may use a large number of actuators and sensors. The performance of a continuous-discrete Kalman filter using multi-sensor observations with irregular sampling patterns is analyzed in terms of the dynamics of the associated (predicted) error-covariance matrix. Irregular sampling may occur as a result of differences in sampling rates and/or lack of synchrony in a geographically-distributed power system. Alternatively, it may also be caused by intermittency (i.e., packet-loss) in the communication link between a sensor and an estimation/control center. We show that the ensemble- and time-averaged error covariance depends only on system parameters and on the characteristic function of the irregular sampling interval of the multi-sensor sampling pattern. We obtain lower and upper bounds on the average error covariance, as well as a necessary condition for its stability, expressed in terms of the region of convergence of the sampling interval characteristic function. In particular, we analyze the effect of the irregular sampling interval variance and higher moments of the multi-sensor sampling pattern and show that the steady-state average error covariance depends primarily on the ensemble-averaged sampling interval with a very minor dependence on the variance, and a negligible dependence on higher-order moments.

11:20 Dongliang Duan, Liuqing Yang, and Louis Scharf. Phasor state estimation from PMU measurements with bad data.

Abstract: The phasor measurement units (PMU) are expected to enhance state estimation in the power grid by providing accurate and timely measurements. However, due to communication errors and equipment failures, some detrimental data can occur among the measurements. The largest residual removal (LRR) algorithm is commonly used for phasor state estimation with bad data. Here, we show that this method cannot guarantee correctness unless data redundancy is very abundant. We then establish the equivalence between the approaches of bad data removal and bad data estimation and subtraction. In addition, we propose two new algorithms by exploiting the sparsity of the bad data. All algorithms are tested by simulations and our projection and minimization (PM) algorithm provides the best performance.

11:40 Miao He, Sugumar Murugesan, and Junshan Zhang. A Markov decision process approach to multi-timescale scheduling and pricing in smart grids with integrated wind generation.

Abstract: In this study, we tackle the challenge of integrating volatile wind generation into the bulk power systems, by leveraging multi-timescale scheduling and pricing with two classes of energy users - traditional energy users and opportunistic energy users (e.g., electric vehicles or smart appliances). In day-ahead scheduling, with the distributional information of wind generation and energy demands, decisions on the optimal procurement of conventional energy supply and the day-ahead retail price are made; in real-time scheduling, with the realization of wind generation, the load of traditional energy users, the real-time prices are announced to manage the demand of opportunistic energy users so as to achieve system-wide reliability. Focusing on the case when the opportunistic energy users are persistent, i.e., they stay in the system until a real-time retail price is acceptable, we formulate the scheduling problem as a multi-timescale Markov decision process with special characteristics. We then show that it can be recast, explicitly, as a classic Markov decision process with continuous state and action spaces, the solution to which can be found via standard techniques.

Signal Processing for Smart Grids, Thursday, Dec. 15, 14–16

14:00 Hanoch Lev-Ari and Aleksandar Stanković. Customized dynamic phasors for power quality control in electric grids.

Abstract: Applications of the dynamic phasor framework are numerous, and include power systems (analysis of unbalanced faults and protection), electric drives (analysis of unbalanced electric machines and of position-dependent loads, torque ripple minimization) and power electronics (model reduction in DC/DC converters, analysis of resonant and high-power converters, control of active filters). While dynamic phasors are intended for near-to-periodic operation, they have a number of useful features: (a) models are time-invariant (autonomous); (b) inputs and states tend to vary slowly compared to the driving frequencies. In this paper we describe a method for application-specific customization of dynamic phasors, intended for use in wide-area monitoring and control of electric power networks. In particular, we propose frequency-selective customization for control of power quality across the grid. Our approach relies on a recently introduced family of generalized dynamic phasors, which we called Phasor Banks, and results in a more compact representation than that obtained with the better-known Fourier dynamic phasors. In turn, customization facilitates efficient communication of phasor information across the power grid, enabling real-time coordinated power-flow control. We also discuss time-selective customization, which allows more accurate determination of the moment of onset of a fault transient. Such information is needed in both fault detection and (networked) fault location applications.

14:20 Neelabh Kashyap, Stefan Werner, and Yih-Fang Huang. Event-triggered multi-area state estimation in power systems.

Abstract: This paper presents a distributed estimation scheme as a possible solution to multi-area state estimation for power systems. The proposed estimation scheme features data-dependent selective sensing and estimation, namely, event-triggered estimation and communication. The triggering event is characterized by the innovation received by the measurements. The proposed scheme can potentially reduce the overhead costs that include communication (bandwidth), data processing and interference, leading to more effective use of the resources.

14:40 Usman Khan and Mohammadreza Doostmohammadian. A sensor placement and network design paradigm for future smart grids.

Abstract: In this paper, we propose a method for sensor placement and communication network design for the purpose of distributed estimation in future smart grids. We use generic observability from structured systems theory to devise sensor placement strategies that are independent of the actual parameter values and are only a function of the underlying structure, i.e., the zero and non-zero pattern, of the physical network. We then use these results to design communication networks among the sensors that ensure observability of the distributed observers formulated on the sensor measurements.

15:00 Mahnoosh Alizadeh, Zhifang Wang, and Anna Scaglione. Demand side management trends in the power grid.

Abstract: The roadmap of Smart Grid includes exploiting the intrinsic elasticity of electricity demand in the future, to make it responsive to the near term cost of supplying generation. This would curb costly peaks of demand and allow greater penetration of renewable energy. The mechanisms serving this purpose are referred to as Demand Side Management (DSM) and Demand-Response (DR) programs. While it is clear that DSM and DR will be indispensable to loosen the control over the generation and decrease the reserve requirements, there is much debate on what is the right architecture for DSM and DR programs. In this paper we discuss current trends that are being considered as candidates for DSM and DR and critically compare them, outlining research directions that should be pursued in the future to overcome this dilemma.

15:20 Vassilis Kekatos and Georgios B. Giannakis. A convex relaxation approach to optimal placement of phasor measurement units.

Abstract: Instrumenting power networks with phasor measurement units (PMUs) facilitates several tasks including optimum power flow, system control, contingency analysis, visualization, and integration of renewable resources, thus enabling situational awareness – one of the key steps toward realizing the smart grid vision. The installation cost of PMUs currently prohibits their deployment on every bus, which in turn motivates their strategic placement across the power grid. As state estimation is at the core of grid monitoring, PMU deployment is optimized here based on estimation-theoretic criteria. Considering both voltage and current PMU readings and incorporating conventionally derived state estimates under the Bayesian framework, PMU placement is formulated as an optimal experimental design task. To obviate the combinatorial search involved, a convex relaxation is also developed to obtain solutions with numerical optimality guarantees. In the tests performed on standard IEEE 14- and 118-bus benchmarks, the proposed relaxation is very close to and oftentimes attains the optimum.

Wireless Communications, Thursday, Dec. 15, 14–16

14:00 Jake Gunther and Todd Moon. An interior point method for a semidefinite relaxation based equalizer incorporating prior information.

Abstract: The problem of maximum likelihood estimation of digital data transmitted over an intersymbol interference channel may be cast as a quadratically constrained quadratic program (QCQP). This problem may be solved approximately but efficiently using a semidefinite relaxation (SDR) technique in which the quadratic objective and constraints are converted into linear functions of a matrix variable. Recently the authors extended the basic SDR technique using maximum a posteriori probability (MAP) estimation to incorporate prior probabilities on the bits. The resulting estimator is a soft-input soft-output equalizer that can be used in iterative (turbo) equalization in situations where true optimal MAP equalization (implemented via the BCJR algorithm) is impractical because of its exponential complexity. This paper develops a custom interior point algorithm using the barrier method to solve the extended SDR problem which is convex. This custom solver is more computationally efficient than a general purpose solver because it can exploit the structure inherent in the equalization problem. Simulation experiments are provided that compare the running times of the new algorithm and a general purpose code (CVX). The new algorithm is more computationally efficient than the more general purpose solver and delivers results with equal accuracy. Refinements in initialization strategies and stopping criteria can improve the computational efficiency of the new algorithm.

14:20 Julia Vinogradova, Nima Sarmadi, and Marius Pesavento. Subspace-based semiblind channel estimation method for fast fading orthogonally coded MIMO-OFDM systems.

Abstract: In this paper, a new semiblind spectrally efficient channel estimation method is presented for fast fading orthogonally coded multiple-input multiple-output orthogonal frequency-division multiplexing (MIMO-OFDM) systems. The proposed method benefits from both the available training symbols inserted in the data frame structure of wireless standards as LTE and WiMAX and the redundancy introduced in the space-time code to enhance channel estimation quality. Our method offers a closed-form solution and performs channel estimation in the time domain in two consecutive steps. First, the subspace containing the true channel vector is estimated from the extended covariance matrix of the received data in a fully blind fashion, and then, the true channel vector is recovered from the obtained subspace using available training symbols. The parsimonious channel characterization that we use decreases the number of parameters required to be estimated. On the one hand, it results in performance improvement as compared to the frequency domain channel estimation methods by coherent processing over all subcarriers. On the other hand, the bandwidth efficiency is enhanced by training overhead reduction as compared to the pure training-based approaches. Moreover, the proposed method is able to eliminate all nonscalar ambiguities inherent to blind channel estimation techniques in two practically important cases, the systems involving single-antenna receivers and the systems involving rotatable codes.

14:40 Pouya Tehrani, Qing Zhao, and Lang Tong. Multi-channel opportunistic spectrum access in unslotted primary systems with unknown models.

Abstract: Multi-channel opportunistic spectrum access in unslotted primary systems is considered. The primary occupancy of each channel is modeled as a general on-off renewal process. The distributions of the busy and idle times, consequently the utilization factors of all channels are unknown to the secondary user. The objective of the secondary user is to identify and exploit the best channel (i.e., the channel with the least primary traffic) through efficient online learning. A channel access policy is constructed that achieves the throughput offered by the best channel under certain mild conditions on the busy/idle time distributions. More specifically, the cost associated with learning the unknown channel occupancy models over a horizon of length T diminishes at the rate of log T /T. The policy is obtained by constructing a hypothetical multi-armed bandit with virtual reward which, while not directly reflecting throughput, preserves the ranking of the channels in terms of throughput.

15:00 Antonio G. Marques, Luis M. Lopez-Ramos, Georgios B. Giannakis, and F. Javier Ramos. Adaptive underlay cognitive radios with imperfect CSI and probabilistic interference constraints.

Abstract: Efficient design of cognitive radios requires secondary users implementing adaptive resource allocation schemes that exploit knowledge of the channel state information (CSI), and limit interference to the primary system. In this paper, stochastic resource allocation algorithms are developed for underlay cognitive radios to maximize the sum-rate of secondary users while adhering to "average power" and "probability of interference" constraints. The latter guarantee that during most of the time the power interfering with primary receivers stays below a certain pre-specified level. Although the resultant optimization problem is non-convex, it exhibits zero-duality gap and can be efficiently solved. The optimal schemes are a function of the link quality of the secondary network, the activity of the primary users, and the Lagrange multipliers associated with the considered constraints. The focus is on developing algorithms that: i) employ stochastic approximation tools to estimate the multipliers; and ii) are able to cope with imperfections present in the CSI of the primary network.

15:20 Paolo Di Lorenzo, Marco Omilipo, and Sergio Barbarossa. Distributed stochastic pricing for sum-rate maximization in femtocell networks with random graph and quantized communications.

Abstract: In this paper, we consider a pricing mechanism aimed at maximizing the sum-rate of a femtocell network in a distributed manner, thanks to a limited exchange of information among neighbor femto access points (FAPs). In a femtocell network, coordination among FAPs is possible exploiting the IP-based backhaul link. In particular, we consider the case where the exchange of information among FAPs is quantized and happens through a network graph (typically a sparse graph), whose links fail randomly across iterations. Using results from stochastic approximation theory, we propose a distributed projection based Robbins-Monro (RM) scheme that converges almost surely (a. s.) on a final allocation equilibrium dependent on the mean graph of the network, even in the presence of such imperfect communication scenario. Numerical results show how the system performance reduces due to the effect of link failures, which cause a lower coordination among FAPs to mitigate interference. Nevertheless, supposing to know the probability with which each link fails, we show how to counteract the effect of failures through a proper weighting of the price coefficients received by the neighbor FAPs. The distributed allocation algorithm is then robust to channel imperfections, whose effect is only to slow down the convergence process.

Beamforming and Array Signal Processing, Thursday, Dec. 15, 16:15–18:15

Paolo Di Lorenzo and Sergio Barbarossa. Optimal beamforming for range-Doppler ambiguity suppression in squinted SAR systems.

Abstract: This paper proposes a method to optimize the beamforming of a planar array in order to maximize the signal to ambiguity ratio, for a general squinted SAR observation geometry. The presence of the receiver thermal noise has been taken into account in the optimization procedure in order to maximize the signal to the overall disturbance ratio. The method works in the joint range-Doppler domain and it provides considerable performance advantages with respect to the uniform weighting case. Most important, the optimization widens the range of Pulse Repetition Frequency (PRF) values that give rise to signal to disturbance ratio values above a desired threshold. This relaxes the choice of the PRF and enables the possibility to widen the swath. The solution is shown to be the generalized eigenvector associated to a pair of matrices depending on the observation geometry, on the Earth reflectivity model and on the PRF. This characteristic allows the fast and reliable computation of the optimal weighting vector and makes the method suitable to be tailored with respect to the specific scope of the mission, i.e. for land, sea or ice exploration, just incorporating the desired predicted (or inferred from previous observation) reflectivity model within the optimization procedure.

Mohammad Zaeri-Amirani, Shahram Shahbazpanahi, and Min Dong. On the design and performance of TDBC-based bi-directional network beamforming.

Abstract: We study and compare the performance of two bi-directional relay network beamforming schemes, namely time division broadcast channel (TDBC) strategy and multiple access broadcast channel (MABC) strategy, under joint optimal power control and beamforming design. Under the presence of a direct link between the two transceivers, we first design the optimal TDBC-based bi-directional network beamformer to minimize the total power consumption in the network subject to quality of service (QoS) constraints. We obtain the optimal second-order cone programming based solution as well as fast gradient-based solution to this optimization problem. With this result, we then numerically compare the beamforming performance of the TDBC approach to that of the MABC approach developed in [1]. We show that the TDBC approach can outperform the MABC approach, under the same rate constraint, provided that the direct link is strong enough.

David Ayllón, Roberto Gil-Pita, and Manuel Rosa. Optimum microphone array for monaural and binaural in-the-canal hearing aids.

Abstract: Modern hearing aids include signal processing algorithms to improve the speech intelligibility by means of a microphone array, which can be monaural or binaural. In both cases, the signals are distorted by the well-known head-shadow effect that must be considered in the design. The main goal of this paper is to find the best microphone array configuration for in-the-canal hearing aids, constrained by the reduced dimension of such devices, in order to maximize the output gain and intelligibility when the array is steered to the desired direction. For this purpose, a total of 12 different array arrangements are compared, in terms of the array gain and intelligibility obtained by a Minimum Variance Distortionless Response (MVDR) beamformer, which also considers the head-shadow effect. The highest gain and intelligibility are obtained by a binaural array composed by a total of 8 microphones, 4 in diamond-shaped alignment in each ear. The results show the level of improvement achieved by increasing the number of microphones as well as using binaural arrays, giving rise to a compromise between the complexity of the array and the desired enhancement.

Mu Zhou and Alle Jan van der Veen. Improved blind separation algorithm for overlapping secondary surveillance radar replies.

Abstract: The secondary surveillance radar (SSR) is a transponder system used in air-traffic control. With the increase in air-traffic, replies from airplanes may overlap in time at ground station receivers, which results in loss of all replies for classic receivers. Blind source separation algorithms were proposed to separate such a mixture by the properties of SSR replies. Two known algebraic algorithms, the Manchester decoding algorithm (MDA) and the multishift zero-constant modulus algorithm, have the best performance but they still have performance degradation in cases with either small overlapping ratios or equal residual carrier frequencies. In this paper, we propose a modified subspace intersection method based on signed URV decompositions to preprocess the received data matrix for MDA. The proposed algorithm works on three successive time slots with the target time slot locating in the center and significantly improves the performance of MDA in all cases. Especially, in cases with small overlapping ratios, it touches the upper bound of the performance it can achieve. It shows the most stable performance compared with previous algorithms.

Arash Khabbazibasmenj and Sergiy A. Vorobyov. A computationally efficient robust adaptive beamforming for general-rank signal model with positive semi-definite constraint.

Abstract: The robust adaptive beamforming problem for general-rank signal model with positive semi-definite (PSD) constraint is considered. The existing approaches for solving the corresponding non-convex optimization problem are iterative methods for which the convergence is not guaranteed. Moreover, these methods solve the problem only suboptimally. We revisit this problem and develop a new beamforming method based on a new solution for the corresponding optimization problem. The new proposed method is iterative and is based on a reformulation and then linearization of a single non-convex difference-of-two-convex functions (DC) constraint. Our simulation results confirm that the new proposed method finds the global optimum of the problem in few iterations and outperforms the state-of-the-art robust adaptive beamforming methods for general-rank signal model with PSD constraint.

Energy Harvesting Wireless Networks, Thursday, Dec. 15, 16:15–18:15

16:15 Paolo Castiglione, Osvaldo Simeone, Elza Erkip, and Thomas Zemen. Energy-harvesting for source-channel coding in cyber-physical systems.

Abstract: The overall energy required to digitize a given physical source can be comparable to the energy required for communication of the produced information bits, especially in cyber-physical sensing systems where radio links are short. When energy is at a premium, this fact calls for energy management solutions that are able to properly allocate the available energy over time between source and channel coding tasks. Energy management is particularly challenging for devices that operate via energy-harvesting, since the controller has to operate without full knowledge of the energy availability in the future. This work addresses the problem of energy allocation over source digitization and communication for a single energy-harvesting sensor. First, optimal policies that minimize the average distortion under constraints on the stability of the data queue connecting source and channel encoders are derived. It is shown that such policies perform independent resource optimizations for the source and channel encoders. The drawback of these policies is that they require an arbitrarily large battery to counteract the variability of the harvesting process and an infinite data queue to mitigate temporal variations in source and channel qualities. Suboptimal policies that do not have such drawbacks are then investigated as well, along with the optimal trade-off distortion vs. delay, which is addressed via dynamic programming tools.

16:35 Omur Ozel, Jing Yang, and Sennur Ulukus. Optimal scheduling over fading broadcast channels with an energy harvesting transmitter.

Abstract: We consider an energy harvesting transmitter sending messages to two users over a fading AWGN broadcast channel. Energy required for communication arrives (is harvested) at the transmitter and a finite capacity battery can store it before being consumed for transmission. Based on a deterministic energy arrival model, we obtain the maximum departure region in a given interval. We obtain the transmission policies that achieve the boundary of the maximum departure region by a directional waterfilling algorithm.

16:55 Kaya Tutuncuoglu and Aylin Yener. Transmission policies for asymmetric interference channels with energy harvesting nodes.

Abstract: Energy harvesting terminals are emerging as favorable alternatives to conventional terminals for wireless (sensor) networking due to environmental concerns and their potential to extend the network lifetime. Stochastic availability of energy for such networks calls for new network design insights on power control and scheduling, particularly in multi-user settings with interference. This paper considers an asymmetric interference channel with two transmitters and two receivers, and seeks optimal power policies to maximize sum capacity in an energy harvesting setting. It is shown that in the asymmetric interference case, the optimal sum capacity for the channel can be found by iteratively employing single-user optimizations, and the corresponding single-user problems are solved using modified water-filling algorithms such as directional water-filling and generalized water-filling. The impact of the proposed iterative algorithm on transmission power policies are demonstrated through simulations.

17:15 Deniz Gunduz and Bertrand Devillers. Two-hop communication with energy harvesting.

Abstract: Communication nodes with the ability to harvest energy from the environment have the potential to operate beyond the timeframe limited by the finite capacity of their batteries; and accordingly, to extend the overall network lifetime. However, the optimization of the communication system in the presence of energy harvesting devices requires a new paradigm in terms of power allocation since the energy becomes available over time. In this paper, we consider the problem of two-hop relaying in the presence of energy harvesting nodes. We identify the optimal offline transmission scheme for energy harvesting source and relay when the relay operates in the full-duplex mode. In the case of a half-duplex relay, we provide the optimal transmission scheme when the source has a single energy packet.

17:35 Srinivas Reddy and Chandra R. Murthy. Duty cycling and power management with a network of energy harvesting sensors.

Abstract: In this paper, we study duty cycling and power management in a network of energy harvesting sensor (EHS) nodes. We consider a one-hop network, where K EHS nodes send data to a destination over a wireless fading channel. The goal is to find the optimum duty cycling and power scheduling across the nodes that maximizes the average sum data rate, subject to energy neutrality at each node. We adopt a two-stage approach to simplify the problem. In the inner stage, we solve the problem of optimal duty cycling of the nodes, subject to the short-term power constraint set by the outer stage. The outer stage sets the short-term power constraints on the inner stage to maximize the long-term expected sum data rate, subject to long-term energy neutrality at each node. Our solutions turn out to have a surprisingly simple form: the duty cycle allotted to each node by the inner stage is simply the fractional allotted power of that node relative to the total allotted power. The optimal sum power allotted is a clipped version of the sum harvested power across all the nodes. The average sum throughput thus ultimately depends only on the sum harvested power and its statistics. We illustrate the performance of the proposed solution through Monte-Carlo simulations.

Wireless Relay Networks, Thursday, Dec. 15, 16:15–18:15

Ebrahim Gharavol and Erik G. Larsson. Robust joint optimization of MIMO interfering relay channels with imperfect CSI.

Abstract: In this paper we deal with the problem of the joint optimization of the precoders, equalizers and relay beamformer of a multiple-input multiple-output interfering relay channel. This network can be regarded az a generalized model for both one-way and two-way relay channels with/without direct interfering links. Unlike the conventional design procedures, we assume that the Channel State Information (CSI) is not known perfectly. The imperfect CSI is described using the norm bounded error framework. We use a system-wide Sum Mean Square Error (SMSE) based problem formulation which is constrained using the transmit power of the terminals and the relay node. The problem at hand, from a worst-case design perspective, is a multilinear, and hence, a nonconvex problem which is also semi-infinite in its constraints. We use a generalized version of the Peterson's lemma to handle the semi-infiniteness and reduce the original problem to a single Linear Matrix Inequality (LMI). However, this LMI is not convex, and to resolve this issue we propose an iterative algorithm based on the alternating convex search methodology to solve the aforementioned problem. Finally simulation results, i.e., the convergence of the proposed algorithm and the SMSE properties, are included to asses the performance of the proposed algorithm.

Luca Sanguinetti and Antonio Alberto D'Amico. Power allocation in two-hop amplify-and-forward MIMO relay systems with QoS requirements.

Abstract: The problem of minimizing the total power consumption while satisfying different quality-of-service requirements in a two-hop multiple-input multiple-output network with a single non-regenerative relay is considered. As shown by Y. Rong, finding the solution to this problem is hard as it is not in a convex form. To overcome this difficulty, in this work a novel approach is proposed that allows to closely approximate the solution of the non-convex problem with that of a convex one easy to solve in closed-form by means of a multi-step procedure of reduced complexity. Computer simulations are used to assess the performance of the proposed solution and to make comparisons with existing alternatives.

Adrian Schad and Marius Pesavento. Multiuser bi-directional communications in cooperative relay networks.

Abstract: In this paper, we extend the concept of the one-directional multiuser peer-to-peer amplify-and-forward relaying scheme to that of a bi-directional two-phase relaying scheme. The relay weights are chosen to maximize the minimal received quality-of-service of all the users under constraints on the individual and the total power at the relays. The computation of the relay weights is accomplished by approximately solving a non-convex optimization problem using a sequential convex programming algorithm of low complexity. In our simulations, the proposed bi-directional relaying scheme outperformed the one-directional multiuser peer-to-peer scheme.

Samer Alabed, Marius Pesavento, and Alex Gershman. Distributed differential space-time coding techniques for two-way wireless relay networks.

Abstract: Recently, several differential distributed space-time coding (DSTC) techniques for two way wireless relay networks (TWRNs) using the amplify and forward (AF) protocol have been proposed, which do not require channel state information (CSI) neither at the relays nor at the terminals. Although the simultaneous bidirectional AF protocol using DSTC has been shown to outperform the conventional four-phase DSTC strategy in the low to medium signal-to-noise ratio (SNR) region, there are mainly three disadvantages associated with it: i) the relay power wasted for transmitting information known at either side, ii) the difficulty to incorporate the direct link between the communicating terminals and iii) the considerable bias at high SNR. In this paper, we propose two differential three-phase DSTC strategies for TWRNs using the AF protocol. In our proposed strategies, the relays do not waste power to transmit known information and the direct link between the communicating terminals can be fully exploited. Simulations show a substantially improved performance in terms of bit error rate of the proposed strategies as compared to the known strategies.

Ahmed Abdelkader, Marius Pesavento, and Alex Gershman. Orthogonalization techniques for single group multicasting in cooperative Amplify-And-Forward networks.

Abstract: We consider the problem of distributed beamforming in amplify-and-forward (AF) relay networks for single-group multicasting, where a single transmitter sends common information symbols to a group of users via cooperating relays. The objective is to design a computationally efficient beamforming scheme to minimize the total transmitted power at the relays subject to quality-of-service (QoS) constraints of all users. We extend the simple orthogonalization techniques, originally developed in the context of conventional broadcasting systems with instantaneous channel state information (CSI) to solve the present problem in the case when second-order statistics of the channel are available. Simulation results show that our technique outperforms the popular SDR-based technique and provides an excellent performance to complexity trade-off over a large range of QoS constraint thresholds.

Batu Krishna Chalise, Yimin D. Zhang, and Moeness Amin. Successive convex approximation for system performance optimization in a multiuser network with multiple MIMO relays.

Abstract: We consider the problem of jointly optimizing amplify-and-forward (AF) multiple-input multiple-output (MIMO) relays and single-antenna receivers for multipoint-to-multipoint (MP2MP) communications using weighted sum mean-square-error (MSE) as a system performance measure. This optimization problem is nonconvex and the optimal solution cannot be obtained in polynomial time. By applying first-order approximation for the quadratic term, we show that this problem can be approximately reformulated as a semidefinite programming (SDP) problem, which is then solved successively in an iterative way. The performance of the proposed scheme is compared with the lower bound (LB) of the global optimal solution that is obtained with increased complexity using the MSE-profile approach, and the bisection and semidefinite relaxation (SDR) techniques. Numerical results show that the performance of the proposed successive convex approximation (SCA) approach is very close to the LB of the global optimal solution and is much better than the zero-forcing MIMO relays.

Efficient Algorithms for Spectrum and Infrastructure Sharing, Friday, Dec. 16, 10:00–12:00

10:00 Oshri Naparstek and Amir Leshem. Fully distributed auction algorithm for spectrum sharing in unlicensed bands.

Abstract: In this paper we introduce a modified auction algorithm that can be applied in a fully distributed manner. The algorithm requires an auctioneer but does not require a shared memory or message passing between bidders. We show that an opportunistic carrier sensing scheme can be used to implement the algorithm without a need for an auctioneer in a way that does not require any message passing, control channel or any other explicit information exchange between users. Bounds on optimality are given as well as simulated results.

10:20 Rami Mochaourab and Eduard Jorswieck. Coalition formation in MISO interference channels.

Abstract: We consider a multi-link multiple-input single-output interference channel. A link in this setting is noncooperative if its transmission does not take into account the interference it generates at other links. Noncooperative operation of the links is generally not efficient. To improve this situation, we study link cooperation via coalitional games. In coalitional games, a player has an incentive to cooperate with other players if this improves his payoff. We model the setting as a game in coalitional form without transferable utility. The players (links) in a coalition either perform zero forcing transmission or Wiener filter precoding to each other. Necessary and sufficient conditions, in terms of a lower signal-to-noise ratio (SNR) threshold, are provided under which all players have the incentive to cooperate and form a grand coalition. In addition, we provide sufficient conditions under which all players have no incentive to cooperate. In this case, the SNR has to be below a specified SNR threshold. Hence, there exists an SNR range in which the links would profit in forming subcoalitions. Therefore, we turn our attention to coalition formation games between the links. We utilize a coalition formation algorithm, called merge-and-split, to determine stable user grouping. Numerical results show that while in the low SNR regime noncooperation is efficient with single-player coalitions, in the high SNR regime all users benefit in forming a grand coalition. Coalition formation shows its significance in the mid SNR regime where subset user cooperation provides joint performance gains.

10:40 Johannes Lindblom, Eleftherios Karipidis, and Erik G. Larsson. Efficient computation of the Pareto boundary for the two-user MISO interference channel with multi-user decoding capable receivers.

Abstract: We study the two-user multiple-input single-output (MISO) interference channel for the scenario where the transmitters have perfect channel state information and employ single-stream beamforming. We assume that the receivers are able of decoding the data from both transmitters. Hence, the signal from the interfering transmitter might be decoded, treating the desired signal as noise, and subtracted from the received signal. We propose an efficient method for finding the Pareto boundary of the corresponding achievable rate region. This method has a complexity which is constant with respect to the number of transmit antennas.

11:00 Emil Björnson, Mats Bengtsson, Gan Zheng, and Björn Ottersten. Computational framework for optimal robust beamforming in coordinated multicell systems.

Abstract: Coordinated beamforming can significantly improve the performance of cellular systems through joint interference management. Unfortunately, such beamforming optimization problems are typically NP-hard in multicell scenarios, making heuristic beamforming the only feasible choice in practice. This paper proposes a new branch-reduce-and-bound algorithm that solves such optimization problems globally, with a complexity suitable for benchmarking and analysis. Compared to prior work, the framework handles robustness to uncertain intercell interference and numerical analysis shows higher efficiency.

11:20 Jianhui Li, Florian Roemer, and Martin Haardt. Efficient relay sharing (EReSh) between multiple operators in amplify-and-forward relaying systems.

Abstract: In this paper, we propose several efficient suboptimal linear beamforming algorithms for an amplify-and-forward relay sharing system between multiple operators, where multiple pairs of base stations and user terminals transmit via a shared relay equipped with multiple antennas. An efficient relay sharing power minimization (EReSh-PM) algorithm is first presented to minimize the relay transmit power while meeting the signal-to-interference-plus-noise ratio requirements at each user terminal. Then efficient relay sharing rate maximization (EReSh-RM) algorithms are designed to maximize the system sum rate under a relay transmit power constraint. In particular, we design EReSh-RM algorithms for single stream and multiple stream transmissions. All the proposed EReSh algorithms are suboptimal, but they are obtained via closed-form solutions. Simulation results demonstrate that they can achieve at least the performance of the state-of-the-art schemes while no iterative procedures are required.

11:40 Amitav Mukherjee and Lee Swindlehurst. Prescient beamforming in multi-user interweave cognitive radio networks.

Abstract: This work investigates a fundamentally novel interweave cognitive radio network where the primary transmitter takes a proactive approach towards improving the accuracy of the spectrum sensing outcomes at the secondary users (SUs). For the single-primary-receiver scenario considered here, the multiantenna primary user constructs its transmit beamforming vector so as to increase the detection probability at the SUs while meeting a desired Quality-of-Service (QoS) target on its own link, by exploiting partial channel state information of the SUs. The objective of such a proactive approach, which we refer to as prescient precoding, is to minimize the probability of interference from SUs at the primary receiver due to imperfect spectrum sensing in fading channels. Numerical results are presented to verify the advantages of the proposed prescient transmission techniques for non-cooperative spectrum sensing scenarios.

Sparse Signal Processing, Friday, Dec. 16, 10:00–12:00

10:00 Sebastian Pazos, Martin Hurtado, Carlos H. Muravchik, and Arye Nehorai. Optimal sensing matrix for sparse linear models.

Abstract: In this paper, we propose a method for designing the optimal sensing of measurements which can be characterized by a sparse linear model. The aim of the sensing operation is not only to reduce the amount of data to be processed but also to reject undesired signals (interferences). As a result, we reduce the computation time and the error for estimating the unknown parameters of the model, with respect to the uncompressed data. Using synthetic data, we analyze the performance of the proposed algorithm. Additionally, we use real radar data to show an application of the method.

10:20 Peng Yang, Gongguo Tang, and Arye Nehorai. Sparsity-enforced regression based on over-complete dictionary.

Abstract: Nonlinear regression has broad applications in various research areas, and kernel-based regression is very popular in machine learning literature. However, the selection of basis function parameters is often difficult. In this paper we propose a new sparsity-enforced regression method based on an overcomplete dictionary. The over-complete dictionary comprises basis functions with quantized parameters, and we employ l1-regularized minimization to obtain a sparse weight vector of the basis. The l1-regularized minimization automatically selects the most suitable basis function parameters. Performance analysis shows that this new method provides improved regression accuracy with small model complexity as measured by the number of non-zero entries of the weight vector.

10:40 Gongguo Tang and Arye Nehorai. Computable performance analysis of Block-Sparsity recovery.

Abstract: In this paper, we employ fixed-point iteration and semidefinite programming to compute performance bounds on the basis pursuit algorithm for block-sparsity recovery. As a prerequisite for optimal sensing matrix design, computable performance bounds would open doors for wide applications in sensor arrays, MIMO radar, DNA microarrays, and many other areas where block-sparsity arises naturally.

11:00 Alireza Makhzani and Shahrokh Valaee. Reconstruction of a generalized joint sparsity model using principal component analysis.

Abstract: In this paper, we define a new Joint Sparsity Model (JSM) and use Principal Component Analysis followed by Minimum Description Length and Compressive Sensing to reconstruct spatially and temporally correlated signals in a sensor network. The proposed model decomposes each sparse signal into two sparse components. The first component has a common support across all sensed signals. The second component is an innovation part that is specific to each sensor and might have a support that is different from the support of the other innovation signals. We use the fact that the common component generates a common subspace that can be found using the principal component analysis and the minimum description length. We show that with this general model, we can reconstruct the signal with smaller samples that are needed by the direct application of the compressive sensing on each sensor.

11:20 Christoph Mecklenbräuker, Peter Gerstoft, and Huajian Yao. Bayesian sparse wideband source reconstruction of Japanese 2011 earthquake.

Abstract: We consider the sparse inversion of seismic recordings from a Bayesian perspective. We have a prior belief that the spatially distributed seismic source should be sparse in the spatial domain. In a Bayesian framework, we assume a Laplace-like prior for a distributed wideband source and derive the corresponding objective function for minimization. We solve a sequence of convex minimization problems for finding a sparse seismic source representation from an underdetermined system of linear measurement equations using teleseismic P waves recorded by an array of sensors. The root mean square reconstruction error for the source distribution is evaluated through numerical simulations.

11:40 Dmitriy Shutin, Sanjeev Kulkarni, and H. Vincent Poor. Stationary point variational Bayesian attribute-distributed sparse learning with ℓ_1 sparsity constraints.

Abstract: The paper proposes a new variational Bayesian algorithm for ℓ_1-penalized multivariate regression with attribute-distributed data. The algorithm is based on (i) the variational Bayesian version of the SAGE algorithm that realizes a training of individual agents in a distributed fashion and (ii) sparse Bayesian learning (SBL) with hierarchical sparsity prior modeling of the agent weights. The SBL introduces constraints on the weights of individual agents, thus reducing the effects of overfitting and removing/suppressing poorly performing agents in the ensemble estimator. The ℓ_1 constraint is introduced using a product of a Gaussian and an exponential probability density function with the resulting marginalized prior being a Laplace pdf. Such a hierarchical formulation of the prior allows for a computation of the stationary points of the variational update expressions for prior parameters, as well as deriving conditions that ensure convergence to these stationary points. Using synthetic data it is demonstrated that the proposed algorithm performs very well in terms of the achieved MSE, and outperforms other algorithms in the ability to sparsify non-informative agents, while at the same time allowing distributed implementation and flexible agent update protocols.

Distributed Estimation, Friday, Dec. 16, 14:00–16:00

Jianshu Chen, Sheng-Yuan Tu, and Ali H. Sayed. Distributed optimization via diffusion adaptation.

Abstract: We develop an iterative diffusion mechanism to optimize a global cost function in a distributed manner over a network of nodes. The cost function is assumed to consist of a collection of individual components, and diffusion strategy allows the nodes to cooperate and diffuse information in real- time. Compared to incremental methods, diffusion methods do not require the use of a cyclic path over the nodes and are more robust to node and link failure.

Arash Mohammadi and Amir Asif. A consensus/fusion based distributed implementation of the particle filter.

Abstract: In view of non-linear, non-Gaussian tracking applications in sensor networks, we propose a consensus/fusion based, distributed implementation of the particle filter (CF/DPF). The proposed distributed implementation addresses three important issues: (i) Extending the idea of the channel filters [1], separate fusion filters are designed to consistently assimilate the local posterior distributions into global posterior by compensating for the common past information between neighbouring nodes typically overlooked in consensus-based distributed particle filter implementations. (ii) The proposed method is not limited to Gaussian approximation for the global posterior density. (iii) Finally, the condition that the consensus step converges between two consecutive observations is partially relaxed. Our numerical simulations verify that the output of the CF/DPF is almost identical to that of the centralized particle filter.

Romain Couillet, Pascal Bianchi, and Jérémie Jakubowicz. Distributed convex stochastic optimization under few constraints in large networks.

Abstract: This article introduces a distributed convex optimization algorithm in a constrained multi-agent system composed by a large number of nodes. We focus on the case where each agent seeks to optimize its own local parameter under few coupling equality and inequality constraints. The objective function is of the power flow type and can be decoupled as a sum of elementary functions, each of which assumed (imperfectly) known by only one node. Under these assumptions, a cost-efficient decentralized iterative solution based on Lagrangian duality is derived, which is provably converging. This new approach alleviates several limitations of algorithms proposed in the stochastic optimization literature. Applications are proposed to decentralized power flow optimization in smart grids.

Swarnendu Kar, Pramod Varshney, and Hao Chen. Spatial whitening framework for distributed estimation.

Abstract: Designing resource allocation strategies for power constrained sensor network in the presence of correlated data often gives rise to intractable problem formulations. In such situations, applying well-known strategies derived from conditional-independence assumption may turn out to be fairly suboptimal. In this paper, we address this issue by proposing an adjacency-based spatial whitening scheme, where each sensor exchanges its observation with their neighbors prior to encoding their own private information and transmitting it to the fusion center. We comment on the computational limitations for obtaining the optimal whitening transformation, and propose an iterative optimization scheme to achieve the same for large networks. We demonstrate the efficacy of the whitening framework by considering the example of bit-allocation for distributed estimation.

Raj Thilak Rajan and Alle Jan van der Veen. Joint ranging and clock synchronization for a wireless network.

Abstract: Synchronization and localization are two key aspects for the coherent functioning of a wireless network. Recently, various estimators have been proposed for pairwise synchronization between two nodes based on time stamp exchanges via two way communication. In this paper, we propose a closed form centralized Global Least Squares (GLS) estimator, which exploits the two way communication information between all the nodes in a wireless network. The fusion center based GLS uses a single clock reference and estimates all the unknown clock offsets, skews and pairwise distances in the network. The GLS estimate for clock offsets and skews is shown to outperform prevalent estimators. Furthermore, a new Cramer Rao Lower Bound (CRLB) is derived for the entire network and the proposed GLS solution is shown to approach the theoretical limits.

Pietro Stinco, Maria S. Greco, Fulvio Gini, and Mario La Manna. NCTR in netted radar systems.

Abstract: The spatial diversity of multistatic systems and the development of efficient fusion strategies have increased the research interest in Non Cooperative Target Recognition (NCTR) techniques. This paper proposes a correlation-based classification algorithm where the information on the target class is provided by the sensors of the system and the final decision is made using a fusion rule that combines the decisions coming from each channel. The proposed fusion rule selects the channels with the best performance and discard those with the worst ones.

Estimation Theory, Friday, Dec. 16, 14:00–16:00

Mélanie Mahot, Frederic Pascal, Philippe Forster, and Jean-Philippe Ovarlez. Robust covariance matrix estimates with attractive asymptotic properties.

Abstract: The Sample Covariance Matrix (SCM) is widely used in signal processing applications which require the estimation of the data covariance matrix. Indeed it exhibits good statistical properties and tractability. However its performance can become very bad in context of non-Gaussian signals, contaminated or missing data. In that case M-estimators provide a good alternative. They have been introduced within the framework of elliptical distributions which encompass a large number of well-known distributions as for instance the Gaussian, the K-distribution or the multivariate Student (or t) distribution. In this paper, we show that with an appropriate normalization, the SCM and M-estimators have the same asymptotic behavior. More precisely, they share the same asymptotic covariance up to a scale factor. Tyler (1983) obtains similar results but we propose here a simpler proof for the case of M-estimators. The important consequence is that the SCM can easily be replaced by M-estimators with minor changes in performance analysis of signal processing algorithms. This result is highlighted by simulations in Direction-Of-Arrival (DOA) estimation using a MUltiple SIgnal Classification (MUSIC) approach. In this paper, we address the case of real data. These results have also been extended to the complex case but, due to the lack of space and for clarity of the presentation, this generalization will be omitted and will be addressed later.

Ami Wiesel. Regularized covariance estimation in scaled gaussian models.

Abstract: We consider regularized covariance estimation in scaled Gaussian settings, e.g., Elliptical distributions, compound-Gaussian processes and spherically invariant random vectors. The classical maximum likelihood (ML) estimate due to Tyler is asymptotically optimal under different criteria and can be efficiently computed even though the optimization is non-convex. We propose a unified framework for regularizing this estimate in order to improve its finite sample performance. Our approach is based on the discovery of hidden convexity within the ML objective, namely convexity on the manifold of positive definite matrices. We regularize the problem using appropriately convex penalties. These allow for shrinkage towards the identity matrix, shrinkage towards a diagonal matrix, shrinkage towards a given positive definite matrix, and regularization of the condition number. We demonstrate the advantages of these estimators using numerical simulations.

Tual Trainini and Eric Moreau. A least squares algorithm for global joint decomposition of complex matrix sets.

Abstract: This paper deals with a new approach for the joint decomposition of complex matrix sets. Such problems arise naturally in various signal processing problems, among which the blind source separation one. The suggested algorithm is based on an Alternating Least Square (ALS) optimization procedure. An improved version is also proposed including a global Enhanced Line Search (ELS) in the recursive procedure. In practice, the main interest of our approach is to take advantage of a greater amount of signal information within the same context, since sets of Hermitian and symmetric complex matrices are combined altogether. Simulations are performed to highlight the advantages of this method as compared to other existing algorithms.

Sheng-Yuan Tu and Ali H. Sayed. Optimal combination rules for adaptation and learning over networks.

Abstract: Adaptive networks, consisting a collection of nodes with learning abilities, are well-suited to solve distributed inference problems and to model various type of self-organizing behavior observed in nature. One important issue in designing adaptive networks is how to fuse the information collected from the neighbors, especially since the mean-square performance of the network depends on the choice of combination weights. We consider the problem of optimal selection of the combination weights and motivate a simple, yet effective, scheme for selecting the weights.

Spectrum Sensing for Cognitive Systems, Friday, Dec. 16, 14:00–16:00

14:00 Daniel Romero and Roberto Lopez-Valcarce. Bandlimited or constant envelope? Exploiting waveform properties in wireless microphone detection.

Abstract: The detection of bandlimited (BL) constant magnitude (CM) signals in white noise of unknown power is analyzed. This is relevant in the context of Dynamic Spectrum Access since Wireless Microphones (WM) typically use analog FM modulation when transmitting in the TV bands, and their bandwidth is much smaller than that of a TV channel. Although detectors exploiting either the BL or the CM properties have been presented in the literature, these two features have not been jointly considered yet. We derive the Generalized Likelihood Ratio test for this setting. Performance is evaluated in the framework for WM simulation developed to assist the IEEE 802.22 Working Group. The detection of bandlimited (BL) constant magnitude (CM) signals in white noise of unknown power is analyzed. This is relevant in the context of Dynamic Spectrum Access since Wireless Microphones (WM) typically use analog FM modulation when transmitting in the TV bands, and their bandwidth is much smaller than that of a TV channel. Although detectors exploiting either the BL or the CM properties have been presented in the literature, these two features have not been jointly considered yet. We derive the Generalized Likelihood Ratio test for this setting. Performance is evaluated in the framework for WM simulation developed to assist the IEEE 802.22 Working Group.

14:20 Jarmo Lundén, Visa Koivunen, Sanjeev Kulkarni, and H. Vincent Poor. Exploiting spatial diversity in multiagent reinforcement learning based spectrum sensing.

Abstract: In this paper a multiband, multiagent reinforcement learning based distributed sensing policy for cognitive radio networks is proposed. In the proposed sensing policy the secondary users (SUs) collaborate with neighboring users by exchanging information locally. The objective is to maximize the amount of free spectrum found for secondary use while guaranteeing a certain probability of detection. The SUs employ spatial diversity through collaborative sensing to control the false alarm rate and thus the probability of finding available spectrum opportunities. The SUs in the cognitive radio network make local decisions based on their own and their neighbors' local test statistics to identify unused spectrum locally. Simulation results show that the proposed sensing policy provides a straightforward approach for obtaining a good tradeoff between sensing more spectrum and the reliability of the sensing results.

14:40 Erik Axell and Erik G. Larsson. Multiantenna spectrum sensing of a Second-Order cyclostationary signal.

Abstract: We consider spectrum sensing of a second-order cyclostationary signal received at multiple antennas. We propose a detector that exploits both the spatial and the temporal correlation of the received signal, without knowing any parameters such as the channel gains or the noise power. The proposed detector is shown numerically to outperform state-of-the-art detectors for spectrum sensing of an OFDM signal, both when using a single antenna and with multiple antennas.

15:00 Deborah Cohen, Eric Rebeiz, Varun Jain, Yonina C. Eldar, and Danijela Čabrić. Cyclostationary feature detection from sub-Nyquist samples.

Abstract: Wideband spectrum sensing which requires detecting the presence or absence of signals in a wideband channel faces multiple practical issues. Current bandwidth limitations of state-of-the-art analog to digital converters require alternative approaches to be considered for wideband sensing. Cyclostationary feature detection is a promising sensing tool which is robust to noise, and takes advantage of the noise stationarity. In this paper, we propose a cyclostationary feature detector that operates on sub-Nyquist samples obtained via either multicoset sampling or the modulated wideband converter analog front-end, and present the receiver's detection performance at low SNRs.

15:20 Geert Leus and Zhi Tian. Recovering second-order statistics from compressive measurements.

Abstract: This paper focuses on the reconstruction of second order statistics of signals under a compressive sensing framework, which can be useful in many detection problems. More specifically, the focus is on general cyclostationary signals that are compressed using random linear projections, and using those compressive measurements, the cyclic power spectrum is retrieved. Subsequently, this can for instance be used to detect the occupation of specific frequency bands, which has applications in cognitive radio. Surprisingly, if the span of the random linear projections is larger than the period of the cyclostationary signals, the cyclic power spectrum can be recovered without putting any sparsity constraints on it, which allows for simple least squares reconstruction methods. This result indicates that significant compression can be realized by directly reconstructing the second-order statistics rather than the random signals themselves.

15:40 Emiliano Dall'Anese and Georgios B. Giannakis. Distributed cognitive spectrum sensing via group sparse total least-squares.

Abstract: Dynamic re-use of licensed bands under the hierarchical spectrum access paradigm calls for innovative network-level sensing algorithms for spectrum opportunity awareness in the frequency, time, and space dimensions. Toward this direction, the present paper develops a distributed spectrum sensing algorithm whereby cognitive radios (CRs) cooperate to localize active primary user (PU) transmitters, and estimate their transmit-power spectral densities. The sensing scheme relies on a parsimonious linear system model that accounts for two forms of sparsity: one due to the narrow-band nature of PU transmissions compared to the large swath of monitored frequencies; and another one emerging when employing a spatial grid of candidate PU locations. Capitalizing on this dual sparsity, and combining the merits of Lasso, group Lasso, and total least-squares (TLS), a group sparse (GS) TLS problem is formulated to obtain hierarchically-sparse model estimates, and cope with model uncertainty induced by channel randomness, and grid-induced model offsets. The GS-TLS problem is collaboratively solved by the CRs in a distributed fashion, using only local message exchanges among neighboring nodes. In spite of the non-convexity of the GS-TLS criterion, the novel distributed algorithm has guaranteed convergence to (at least) a locally optimal solution. The analytical findings are corroborated by numerical tests.

Deterministic and Probabilistic Toolsets for High-Dimensional Optimization, Friday, Dec. 16, 16:15–18:15

16:15 Andrew Harms, Waheed U. Bajwa, and Robert Calderbank. Faster than nyquist, slower than tropp.

Abstract: The sampling rate of analog-to-digital converters is severely limited by underlying technological constraints. Recently, Tropp et al. proposed a new architecture, called a random demodulator (RD), that attempts to circumvent this limitation by sampling sparse, bandlimited signals at a rate much lower than the Nyquist rate. An integral part of this architecture is a random bi-polar modulating waveform (MW) that changes polarity at the Nyquist rate of the input signal. Technological constraints also limit how fast such a waveform can change polarity, so we propose an extension of the RD that uses a run-length limited MW which changes polarity at a slower rate. We call this extension a constrained random demodulator (CRD) and establish that it enjoys theoretical guarantees similar to the RD and that these guarantees are directly related to the power spectrum of the MW. Further, we put forth the notion of knowledge-enhanced CRD in the paper. Specifically, we show through simulations that matching the distribution of spectral energy of the input signal with the power spectrum of the MW results in the CRD performing better than the RD of Tropp et al.

16:35 Kun Qiu and Aleksandar Dogandžić. A GEM hard thresholding method for reconstructing sparse signals from quantized noisy measurements.

Abstract: We develop a generalized expectation-maximization (GEM) algorithm for sparse signal reconstruction from quantized noisy measurements. The measurements follow an underdetermined linear model with sparse regression coefficients, corrupted by additive white Gaussian noise having unknown variance. These measurements are quantized into bins and only the bin indices are used for reconstruction. We treat the unquantized measurements as the missing data and propose a GEM iteration that aims at maximizing the likelihood function with respect to the unknown parameters. We prove that, under certain mild conditions, our GEM iteration converges monotonically to its fixed point. We compare the proposed scheme with the state-of-the-art convex relaxation method for quantized compressed sensing via numerical simulations.

16:55 Anastasios Kyrillidis and Volkan Cevher. Recipes on hard thresholding methods.

Abstract: Compressive sensing (CS) is a data acquisition and recovery technique for finding sparse solutions to linear inverse problems from sub-Nyquist measurements. CS features a wide range of computationally efficient and robust signal recovery methods, based on sparsity seeking optimization. In this paper, we present and analyze a class of sparse recovery algorithms, known as hard thresholding methods. We provide optimal strategies on how to set up these algorithms via basic "ingredients" for different configurations to achieve complexity vs. accuracy tradeoffs. Simulation results demonstrate notable performance improvements compared to state-of-the-art algorithms both in terms of data reconstruction and computational complexity.

17:15 Philip Schniter. Exploiting structured sparsity in Bayesian experimental design.

Abstract: In this paper, we merge Bayesian experimental design with turbo approximate message passing (AMP) algorithms for the purpose of recovering structured-sparse signals using a multi-step adaptive compressive-measurement procedure. First, we show that, when the signal posterior is Gaussian, a waterfilling approach can be used to adapt the measurement matrix in a way that expected information gain is maximized. Next, we propose four methods of approximating AMP's non-Gaussian marginal posteriors by a Gaussian joint posterior. One of these methods requires only point estimates of the signal, and leads to a novel kernel adaptation scheme that works even with non-Bayesian signal recovery algorithms like LASSO. Finally, we demonstrate (empirically) that our adaptive turbo AMP yields estimation performance very close to the support-oracle bound.

17:35 Sangnam Nam, Mike Davies, Michael Elad, and Rémi Gribonval. Recovery of cosparse signals with greedy analysis pursuit in the presence of noise.

Abstract: The sparse synthesis signal model has enjoyed much success and popularity in the recent decade. Much progress ranging from clear theoretical foundations to appealing applications has been made in this field. Alongside the synthesis approach, an analysis counterpart has been used over the years. Despite the similarity, markedly different nature of the two approaches has been observed. In a recent work, the analysis model was formally formulated and the nature of the model was discussed extensively. Furthermore, a new greedy algorithm (GAP) for recovering the signals satisfying the model was proposed and its effectiveness was demonstrated. While the understanding of the analysis model and the new algorithm has been broadened, the stability and the robustness against noise of the model and the algorithm have been mostly left out. In this work, we adapt and propose a new GAP algorithm in order to deal with the presence of noise. Empirical evidence for the algorithm is also provided.

17:55 Ulugbek S. Kamilov, Vivek K. Goyal, and Sundeep Rangan. Generalized approximate message passing estimation from quantized samples.

Abstract: Estimation of a vector from quantized linear measurements is a common problem for which simple linear techniques are sometimes greatly suboptimal. This paper summarizes the development of generalized approximate message passing (GAMP) algorithms for minimum mean-squared error estimation of a random vector from quantized linear measurements, notably allowing the linear expansion to be overcomplete or undercomplete and the scalar quantization to be regular or non-regular. GAMP is a recently-developed class of algorithms that uses Gaussian approximations in belief propagation and allows arbitrary separable input and output channels. Scalar quantization of measurements is incorporated into the output channel formalism, leading to the first tractable and effective method for high-dimensional estimation problems involving non-regular scalar quantization. Non-regular quantization is empirically demonstrated to greatly improve rate-distortion performance in some problems with oversampling or with undersampling combined with a sparsity-inducing prior. Under the assumption of a Gaussian measurement matrix with i.i.d. entries, the asymptotic error performance of GAMP can be accurately predicted and tracked through the state evolution formalism.

Sensor Network

Toon van Waterschoot and Geert Leus. Static field estimation using a wireless sensor network based on the finite element method.

Abstract: In this paper, we propose a novel framework for field estimation in a wireless sensor network (WSN). The fundamental problem of estimating field values at locations where no WSN measurements are available is tackled by including a physical field model in the form of a partial differential equation (PDE). If the PDE is discretized in the spatiotemporal domain by use of the finite element method (FEM), then the physical field model reduces to a set of linear equations that can be elegantly combined with the WSN field measurements in a constrained optimization problem. In contrast to existing approaches, we do not require the driving source function or the locations of point sources to be known. Instead, we assume limited prior knowledge on the nature of the field and/or source functions, such as a sparsity or nonnegativity prior, for obtaining a unique solution of the otherwise underdetermined problem of joint field and source estimation. Within the proposed framework, we derive a cooperative estimation algorithm for static 2-D fields governed by a Poisson PDE. Simulation results illustrate that a significant improvement in field estimation accuracy can be obtained, compared to the cases when only WSN measurements (without a physical model) or only the FEM (without WSN measurements) are used.

Harish K Chintakunta and Hamid Krim. Detection and tracking of systematic time-evolving failures in sensor networks.

Abstract: Sensor networks are often deployed to monitor hazardous environments. Several events/phenomenon in such environments may cause spatially and temporally correlated failures in the network. We present here, a low complexity distributed algorithm for detecting and tracking such failures. We assume that nodes inside the failure region are either destroyed or unable to communicate with any other node. The algorithm presented here does not assume any co-ordinate information for the nodes. We evaluate the algorithm using some simulation.

Richard K. Martin, Christopher R. Anderson, Ryan Thomas, and Amanda King. Modelling and analysis of radio tomography.

Abstract: Radio tomographic imaging (RTI) has recently been proposed for tracking object location via radio waves without requiring the objects to transmit or receive radio signals. The position is extracted by inferring which voxels are obstructing a subset of radio links in a dense wireless sensor network. This paper proposes a refined model for signal attenuation in RTI based on measured data, which is used to provide analytic support for previous qualitative observations. We also provide an analytic method for choosing the weighting of the regularization term, and investigate methods for dealing with negative observations caused by noise.

Jieqi Yu, Sanjeev Kulkarni, and H. Vincent Poor. A distributed spring model algorithm for sensor localization using dimension expansion and hyperbolic tangential force.

Abstract: This paper proposes two improvements of the spring model algorithm for solving localization problems in a wireless sensor network with anchors. First, the two-dimensional localization problem is solved in three-dimensional space. This “dimension expansion” can effectively prevent the spring model algorithm falling into local minima. Second, the Hooke spring force (linear) is replaced by hyperbolic tangential force (a continuous function that emulates the sign function). This significantly improves the robustness of the algorithm in the presence of multiplicative noise. The efficacy of these two techniques are demonstrated by several simulations, especially in a scenario with anchor points of longer broadcasting radius than other sensors.

Hector M Lugo-Cordero, Abigail Fuentes-Rivera, Ratan Guha, Kejie Lu, and Domingo A. Rodriguez. Multimodal species identification in wireless sensor networks.

Abstract: This paper deals with a multimodal approach to identifying species in a Versatile Service-Oriented Wireless Mesh Sensor Network. This type of network is distinguished by the presence of heterogeneous networks, which may posses low storage capabilities. Hence, an optimal multimodal classifier is introduced, which employs audio and image features to enhance its performance in noisy environments. The classifier is a neural network which is evolved with an evolutionary algorithm. Results demonstrate that the classifier can achieve high performance, which is not degraded as it scales to classifying more classes.

Tracking Problems

Philippe Goy, François Vincent, and Jean-Yves Tourneret. Clutter rejection for MTI radar using a single antenna and a long integration time.

Abstract: Moving Target Indicators (MTI) are airborne radar systems designed to detect and track moving vehicles or aircrafts. In this paper, we address the problem of detecting hazardous collision targets to avoid them. One of the best known solutions to solve this problem is given by the so-called Space-Time Adaptive Processing (STAP) algorithms which optimally filter the target signal from interference and noise exploiting the specific relationship between Direction Of Arrival (DOA) and Doppler for the ground clutter. However, these algorithms require an antenna array and multiple reception channels that increase cost and complexity. The authors propose an alternative solution using a single antenna only. In addition to the standard Doppler shift related to the radial speed, the orthoradial speed of any target can be estimated if using a long integration time. Dangerous targets and ground clutter have different signatures in the radial-orthoradial velocity plane. An optimal detector is then proposed based on the oblique projection onto the signal subspace orthogonal to the clutter subspace. The theoretical performances of this detector are derived and a realistic radar scene simulation shows the benefits of this new MTI detector.

Jimeng Zheng and Mostafa Kaveh. Persistently active block sparsity with application to direction-of-arrival estimation of moving sources.

Abstract: In this paper, the problem of recovering inconsistent sparse models from multiple observations is considered. A new method is developed by introducing a novel objective function, which exploits both block-level and element-level sparsities and promotes persistence in activity within a block. Then, we use a SVD-based method to reduce its computational complexity. Application of the method to the Direction-Of-Arrival (DOA) estimation of moving sources using a sensor array is presented and a simulation example is shown as a demonstration of the promising performance of the method in a moving DOA setting, particularly when sources are very close to each other.

Ashkan Panahi and Mats Viberg. Fast LASSO based DOA tracking.

Abstract: In this paper, we propose a sequential, fast DOA tracking technique using the measurements of a uniform linear sensor array in the far field of a set of narrow band sources. Considering LASSO optimization as a Bayesian estimation, we first define a class of prior distributions suitable for the sparse representation of the model and discuss its relation to the priors over DOAs and waveforms. Inspired by the Kalman filtering method, we introduce a nonlinear sequential filter on this family of distributions. We derive the filter for a simple random walk movement model of the DOAs. The method consists of consecutive implementation of weighted LASSO optimizations using each new measurement and updating the LASSO weights for the next step.

Shuo Zhang and Yaakov Bar-Shalom. Particle filter processing of out-of-sequence measurements: Exact Bayesian solution.

Abstract: In a centralized target tracking system, local sensors send raw measurements to the fusion center for processing. Each measurement comes with a "time stamp" indicating when the observation was made. Due to different data pre-processing and transmission times, the measurements received at the fusion center exhibit different delays. This can lead to the situations where measurements from the same target arrive out of sequence and such measurements are called out-of-sequence measurements (OOSMs). With the development of multisensor systems, the OOSM problem has been gaining more attention. This paper considers the problem of out-of-sequence measurement (OOSM) processing when the filtering technique used at the tracker is a particle filter (PF). First, the exact Bayesian algorithm for updating with OOSMs is derived. Then, the PF implementation of the exact Bayesian algorithm, called A-PF, is developed. Since A-PF is rooted in exact Bayesian inference, if the number of particles is sufficiently large, A-PF is the one (and the only one) that is able to achieve the optimal performance obtained from the in-sequence processing. This is confirmed by the simulation results. Also, it is shown that the performance of A-PF is always superior to previous (heuristic) PF-based algorithms with the same number of particles.

Sirin Nitinawarat, George Atia, and Venugopal Veeravalli. Efficient target tracking using mobile sensors.

Abstract: We discuss a simple mathematical model that studies tracking of a moving target by multiple mobile sensors in the framework of a partially observable Markov decision process. Applications include the use of a fleet of unmanned aerial vehicles for purposes such as search, surveillance, and target tracking. We propose computationally efficient approximate policies for controlling the mobile sensors, and provide a guarantee on their performance losses from the optimal policy. Simulation results show that our proposed policies do perform close to the optimum for certain small spatially stationary models in which a mobile sensor can always move as fast as the target.

Phani Chavali and Arye Nehorai. Multiple Rao-Blackwellized particle filtering for target tracking in urban environments.

Abstract: We propose a new filtering algorithm for joint tracking of multiple target states and the channel state between each pair of antennas in a radar network. The problem of tracking multiple targets in complex scenarios, such as an urban environment, poses a computational challenge as standard particle filtering (SPF) requires large number of particles to obtain an accurate estimate of the high-dimensional state vector. In this paper, we develop a hybrid filter based on the combination of multiple particle filtering (MPF) and Rao-Blackwellized particle filtering (RBPF) by exploiting the structure in the state-space model. Numerical simulations show that the proposed multiple Rao-Blackwellized particle filtering (MRBPF) performs better than the SPF and the RBPF.