Sparse and Low Rank Approximation 11w5036
March 6 – 11, 2011

MEALS

*Breakfast (Buffet): 7:00–9:30 am, Sally Borden Building, Monday–Friday
*Lunch (Buffet): 11:30 am–1:30 pm, Sally Borden Building, Monday–Friday
*Dinner (Buffet): 5:30–7:30 pm, Sally Borden Building, Sunday–Thursday
Coffee Breaks: As per daily schedule, 2nd floor lounge, Corbett Hall
***Please remember to scan your meal card at the host/hostess station in the dining room for each meal.**

MEETING ROOMS

All lectures will be held in Max Bell 159 (Max Bell Building accessible by walkway on 2nd floor of Corbett Hall). LCD projector, overhead projectors and blackboards are available for presentations. Note that the meeting space designated for BIRS is the lower level of Max Bell, Rooms 155–159. Please respect that all other space has been contracted to other Banff Centre guests, including any Food and Beverage in those areas.

Sunday

16:00	Check-in begins (Front Desk - Professional Development Centre - open 24 hours) Lecture rooms available after 16:00 (if desired)
17:30–19:30	Buffet Dinner, Sally Borden Building
20:00	Informal gathering in 2nd floor lounge, Corbett Hall Beverages and a small assortment of snacks are available on a cash honor system.

Monday

7:00–8:45	Breakfast
8:45–9:00	Introduction and Welcome by BIRS Station Manager, Max Bell 159
9:00–9:45	Albert Cohen Sparse high dimensional polynomial approximation of parametric PDEs
9:45–10:15	Thomas Strohmer Compressive Sensing - The Best or the Worst of Two Worlds?
10:15–10:45	Coffee Break, 2nd floor lounge, Corbett Hall
10:45–11:30	Jean-Luc Starck Sparse analysis of the PLANCK cosmic microwave background data
11:30–12:00	Ali Pezeshki
12:00–13:00	Lunch
13:00–14:00	Guided Tour of The Banff Centre; meet in the 2nd floor lounge, Corbett Hall
14:00–14:30	Yonina Eldar Sub-Nyquist sampling and identification of LTV systems
14:30–15:00	Rayan Saab Sigma-Delta Quantization for Compressed Sensing
15:00–15:30	Coffee Break, 2nd floor lounge, Corbett Hall.
15:30–16:00	Arian Maleki Suboptimality of nonlocal means on edges
16:00–16:30	Matthew Herman Grid-Free Denoising of Point-Cloud Data via Non-Local Regularization
17:30–19:30	Dinner

Tuesday

7:00–9:00	Breakfast
9:00–9:45	Ingrid Daubechies
9:45–10:15	Maryam Fazel
	Tight and Simple Recovery Conditions for Low Rank Matrices from Linear Measurements
10:15–10:45	Coffee Break, 2nd floor lounge, Corbett Hall
10:45–11:30	Ben Recht
	The Convex Geometry of Linear Inverse Problems
11:30–12:00	Götz Pfander
	Time-frequency structured measurement matrices: spark, coherence and RIP
12:00–13:30	Lunch
13:45	Group Photo; meet on the front steps of Corbett Hall
14:00–14:30	Deanna Needell
	Acceleration of Randomized Kaczmarz Method via the Johnson-Lindenstrauss Lemma
14:30–15:00	Simon Foucart
	Compressive Sensing insight into the geometry of quasi-Banach spaces
15:00–15:30	Coffee Break, 2nd floor lounge, Corbett Hall
15:30–16:00	Jan Vybíral
	Learning Functions of Few Arbitrary Linear Parameters in High Dimensions
16:00–16:30	Mauricio Sacchi
	Application of sparse and rank reduction reconstruction to large-scale industrial seismic reconstruction problems
16:30–17:00	Stefan Kunis
	Stability of sparse fast Fourier transforms
17:30–19:30	Dinner

Wednesday

7:00–9:00	Breakfast
9:00–9:45	Nathan Srebro
	Matrix Learning: A Tale of Two Norms
9:45–10:15	Massimo Fornasier
	The Projection Method for Dynamical Systems of Interacting Agents in High-Dimension.
10:15–10:45	Coffee Break, 2nd floor lounge, Corbett Hall
10:45–11:15	Volodya Temlyakov
	Lebesgue type inequalities for greedy approximation
11:15–11:45	Felix Herrmann
	Compressive Sensing and Sparse Recovery in Exploration Seismology
11:45–12:15	Richard Baraniuk
	1-bit Compressive Sensing and Binary Stable Embeddings
12:15–13:30	Lunch
	Free Afternoon
17:30–19:30	Dinner
20:00–21:00	Pete Casazza
	Constructing sparse frames

Thursday	
7:00–9:00	Breakfast
9:00–9:45	Andrea Montanari
9:45–10:15	Mark Iwen Approximation of points on low-dimensional manifolds via compressive measurements
10:15–10:45	Coffee Break, 2nd floor lounge, Corbett Hall
10:45–11:30	Justin Romberg Architectures for compressive sampling of correlated signals
11:30–12:00	Felix Krahmer New and improved Johnson-Lindenstrauss embeddings via the Restricted Isometry Property
12:00–13:30	Lunch
14:00–14:30	Hassan Mansour Weighted ℓ_1 Minimization: Stability, robustness, and some implications
14:30–15:00	Alekh Agarwal Noisy matrix decomposition via convex relaxation: Optimal rates in high dimensions
15:00–15:30	Coffee Break, 2nd floor lounge, Corbett Hall
15:30–16:00	Petros Boufounos Sparse cost function minimization
16:00–16:30	Vivek Goyal Sparse Signal Estimation: A Bayesian Perspective
16:30–17:00	Robert Calderbank How and When to Listen
17:30–19:30	Dinner
Friday	
7:00–9:00	Breakfast
9:00–10:00	Discussion Session
10:00–10:30	Coffee Break, 2nd floor lounge, Corbett Hall
11:30–13:30	Lunch
Checkout by 12 noon.	

** 5-day workshops are welcome to use BIRS facilities (2nd Floor Lounge, Max Bell Meeting Rooms, Reading Room) until 3 pm on Friday, although participants are still required to checkout of the guest rooms by 12 noon. **

Sparse and Low Rank Approximation
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ABSTRACTS
(in alphabetic order by speaker surname)

Speaker: **Alekh Agarwal** (UC Berkeley)
Title: *Noisy matrix decomposition via convex relaxation: Optimal rates in high dimensions*
Abstract: We analyze a class of estimators based on convex relaxation for solving high-dimensional matrix decomposition problems. The observations are the noisy realizations of the sum of an (appproximately) low rank matrix $\Theta^\star$ with a second matrix $\Gamma^\star$ endowed with a complementary form of low-dimensional structure. We derive a general theorem that gives upper bounds on the Frobenius norm error for an estimate of the pair $(\Theta^\star, \Gamma^\star)$ obtained by solving a convex optimization problem that combines the nuclear norm with a general decomposable regularizer. We then specialize this result to two cases that have been studied in the context of robust PCA: low rank plus an entrywise sparse matrix, and low rank plus a columnwise sparse matrix. For both models, our theory yields non-asymptotic Frobenius error bounds for both for deterministic and stochastic noise matrices, and applies to matrices $\Theta^\star$ that can be exactly or approximately low rank, and matrices $\Gamma^\star$ that can be exactly or approximately sparse. Moreover, for the case of stochastic noise matrices, we establish matching lower bounds on the minimax error, showing that our results cannot be improved beyond constant factors. The sharpness of our theoretical predictions is confirmed by numerical simulations.

– Joint work with Sahand Negahban and Martin Wainwright.

Speaker: **Richard Baraniuk** (Rice University)
Title: *1-bit Compressive Sensing and Binary Stable Embeddings*
Abstract: The Compressive Sensing (CS) framework aims to ease the burden on analog-to-digital converters (ADCs) by reducing the overall number of samples such devices must acquire. In practice, this translates to lower sampling rates that are more easily achieved by current hardware designs. However, an overlooked, yet primary bottleneck on sampling rates is quantization; specifically, with current hardware ADC designs, higher bit-depth quantization can be achieved only at lower sampling rates. In this talk, we consider a different approach to improving ADCs by shifting the emphasis from the sampling rate to the number of bits per measurement. We explore the extreme case where each measurement is quantized to just one bit, representing its sign. In this case, the quantizer reduces to a simple comparator, which enables the design of extremely high rate ADCs. Our key theoretical construct is the notion of a "Binary Stable Embedding", a property that ensures stable reconstruction from 1-bit measurements. In addition to new theory, I will describe some of the latest algorithmic developments for 1-bit signal recovery and conclude with a discussion of the current state of 1-bit CS.

– This is joint work with Jason Laska, Wotao Yin, Laurent Jacques, Zaiwen Wen, and Petros Boufounos.

Speaker: **Petros Boufounos** (Mitsubishi Electric Research Laboratories)
Title: *Sparse cost function minimization*
Abstract: The success of Compressive Sensing (CS) has reinforced the importance of sparsity in signal processing and machine learning. However, it has also focused the attention to sparsity-constrained optimization of quadratic cost functions, omnipresent in sensing applications. In this talk I will present recent work in sparsity constrained optimization of arbitrary cost functions. Our work generalizes the well-established Restricted Isometry Property (RIP) to a stability condition on the Hessian of the cost function. Furthermore, we discuss the Gradient Support Pursuit (GraSP), and algorithm that generalizes known CS algorithms to perform sparsity constrained minimization of arbitrary cost functions. We conclude with some usage examples.

– Joint work with Sohail Bahmani and Bhiksha Raj.

Speaker: **Robert Calderbank** (Duke University)
Title: *How and When to Listen*
Abstract: Reed Muller codes are old. They were among the very first algebraic error correcting codes to be discovered and analyzed and they find application today as spreading sequences in spread spectrum wireless communication.

Compressed sensing is much more modern. The idea of capturing attributes of a signal with very few measurements has wide applicability and we will describe how second order Reed-Muller codes lead to a new deterministic framework for communication in wireless networks.

We address two particular challenges. The first is a wireless uplink where mobile users in some geographic area need to register with a base station. The second is the distribution of information in a wireless sensor network.

Speaker: **Pete Casazza** (University of Missouri)
Title: *Constructing Sparse Frames*
Abstract: We will look at some algorithms for constructing the sparsest tight frames and the sparsest tight fusion frames.

Speaker: **Yonina Eldar** (Technion Haifa)
Title: *Sub-Nyquist sampling and identification of LTV systems*
Abstract: Identification of time-varying linear systems, which introduce both time-shifts (delays) and frequency shifts (Doppler-shifts), is a central task in many engineering applications. We consider the problem of identification of underspread linear systems (ULSs), whose responses lie within a unit-area region in the delayDoppler space, by probing them with a known input signal. It is shown that sufficiently-underspread parametric linear systems, described by a finite set of delays and Doppler-shifts, are identifiable from a single observation as long as the timebandwidth product of the input signal is proportional to the square of the total number of delayDoppler pairs in the system. In addition, an algorithm is developed that enables identification of parametric ULSs from an input train of pulses in polynomial time by exploiting recent results on sub-Nyquist sampling for time delay estimation and classical results on recovery of frequencies from a sum of complex exponentials. Finally, application of these results to super-resolution target detection using radar is discussed. Specifically, it is shown that the proposed procedure allows to distinguish between multiple targets with very close proximity in the delayDoppler space, resulting in a resolution that substantially exceeds that of standard matched-filtering based techniques without introducing leakage effects inherent in compressed sensing-based methods.

– Based on joint work with Waheed Bajwa and Kfir Gedalyahu.

Speaker: **Maryam Fazel** (University of Washington)
Title: *Tight and Simple Recovery Conditions for Low Rank Matrices from Linear Measurements*
Abstract: ecovering sparse vectors and low-rank matrices from noisy linear measurements has been the focus of much recent research. In this talk, we show how several classes of robust recovery conditions can be extended directly from vectors to matrices in a simple and transparent way, leading to the tightest known restricted isometry and nullspace conditions on the measurement map for matrix recovery. Results rely on the ability to vectorize matrices through the use of a key singular value inequality.

– Based on joint work with Samet Oymak, Karthik Mohan, and Babak Hassibi.

Speaker: **Massimo Fornasier** (RICAM Linz)
Title: *The Projection Method for Dynamical Systems of Interacting Agents in High-Dimension*
Abstract: In our recent research activity (`http://hdsparse.ricam.oeaw.ac.at/`) we formulated and explored new models and methods for

- compressive sensing and algorithms;

- learning functions in high-dimension;
- particle, kinetic, and hydrodynamic models of social interaction.

We are interested to address the combination of these ingredients for learning, simulation, and control of particle systems, kinetic equations, and fluid dynamics models of interacting agents in high-dimension. In particular, in this talk we explore how concepts of high-dimensional data compression via random projections onto lower-dimensional spaces can be applied for tractable simulation of certain dynamical systems modeling complex interactions. In such systems, one has to deal with a large number of agents (typically millions) in spaces of parameters describing each agent of high-dimension (thousands or more). Even with todays powerful computers, numerical simulations for such systems are prohibitively expensive. We propose an approach for the simulation of dynamical systems governed by functions of adjacency matrices in high-dimension, by random projections via Johnson-Lindenstrauss embeddings, and recovery by compressed sensing techniques. We call this technique the Projection Method. We further show how these concepts can be generalized to work for associated kinetic equations, by addressing the phenomenon of the delayed curse of dimensionality, known in information based complexity for numerical integration problems.

– Joint work with Jan Haskovec and Jan Vybíral.

Speaker: **Simon Foucart** (Drexel University)
Title: *Compressive Sensing insight into the geometry of quasi-Banach spaces*
Abstract: This talk will be centered around two major results on the geometry of finite-dimensional ℓ_1-spaces, namely the estimation of the Gelfand widths of their unit balls and Kashin's orthogonal decomposition theorem. We will show how the theory of Compressive Sensing simplifies the proofs of these results and allows to extend them to finite-dimensional ℓ_p-spaces with $0 < p \leq 1$. While it is well-known that Compressive Sensing methods yield the upper estimate for the Gelfand with of ℓ_1^N in ℓ_2^N, we will point out that they also provide an easy argument for the lower estimate. Next, we will explain how to obtain Kashin's decomposition from the observation that the null-space of a matrix with the restricted isometry property is almost Euclidean when endowed with the ℓ_1-norm.

Speaker: **Felix Herrman** (University of British Columbia)
Title: *Compressive Sensing and Sparse Recovery in Exploration Seismology*
Abstract: Full-waveform inversion relies on large multi-experiment data volumes. While improvements in acquisition and inversion have been extremely successful, the current push for higher quality models reveals fundamental shortcomings handling increasing problem sizes numerically. To address this fundamental issue, we propose a randomized dimensionality-reduction strategy motivated by recent developments in stochastic optimization and compressive sensing. In this formulation conventional Gauss-Newton iterations are replaced by dimensionality-reduced sparse recovery problems with source encodings.

– This is joint work with Aleksandr Aravkin, Tristan van Leeuwen, and Xiang Li

Speaker: **Vivek Goyal** (MIT)
Title: *Sparse Signal Estimation: A Bayesian Perspective*
Abstract: Most theoretical results in sparse approximation are based on considering the signal to be an unknown deterministic quantity. Since they apply for any signal within a class, these results are inherently conservative. This talk will focus on results obtained under Bayesian formulations using the replica method, a non-rigorous but quantitatively successful technique from statistical physics. The replica method provides an exact asymptotic analysis for many estimators, including basis pursuit, lasso, linear estimation with thresholding, and zero norm-regularized estimation. It reduces the analysis of high-dimensional problems to the study of scalar estimation problems, and it gives results that are more encouraging for compressed sensing. The talk will also include some results for a semi-Bayesian setting in which conditional rank information is known.

– Based on joint work with Alyson Fletcher and Sundeep Rangan.

Speaker: **Matthew Herman** (UCLA)
Title: *Grid-Free Denoising of Point-Cloud Data via Non-Local Regularization*
Abstract: We present new results of denoising point cloud data using non-local techniques. The work is motivated by a problem in remote sensing where 3-D point clouds are encountered in laser radar applications. The novelty of our approach is that, unlike current methods, we do NOT force the data onto a grid. This preserves the subtle geometric information in the point cloud, and permits the identification of 3-D structures in the data. In particular, we are able to denoise objects of codimension 1 and 2 simultaneously. This approach can be extended to point clouds in higher dimensions, and thus has the potential to be useful in many applications.

Speaker: **Mark Iwen** (Duke University)
Title: *Approximation of points on low-dimensional manifolds via compressive measurements*
Abstract: We consider the approximate reconstruction of points, $x \in \mathbb{R}^D$, which are close to a given compact d-dimensional submanifold, M, of $\mathbb{R}^D$ using a small number of linear measurements of x (i.e., compressive measurements). We provide a simple algorithmic reconstruction algorithm based on Geometric Wavelet constructions, and prove theoretical error guarantees of various flavors.

– Joint work with Mauro Maggioni

Speaker: **Felix Krahmer** (University of Bonn)
Title: *New and improved Johnson-Lindenstrauss embeddings via the Restricted Isometry Property*
Abstract: The Johnson-Lindenstrauss (JL) Lemma states that any set of p points in high dimensional Euclidean space can be embedded into $O(\delta^{-2}\log(p))$ dimensions, without distorting the distance between any two points by more than a factor between $1-\delta$ and $1+\delta$. We establish a new connection between the JL Lemma and the Restricted Isometry Property (RIP), a well-known concept in the theory of sparse recovery often used for showing the success of ℓ_1-minimization.

Consider an $m \times N$ matrix satisfying the (k, δ_k)-RIP with randomized column signs and an arbitrary set E of $O(e^k)$ points in $\mathbb{R}^N$. We show that with high probability, such a matrix with randomized column signs maps E into $\mathbb{R}^m$ without distorting the distance between any two points by more than a factor of $1 \pm 4\delta_k$. Consequently, matrices satisfying the Restricted Isometry of optimal order provide optimal Johnson-Lindenstrauss embeddings up to a logarithmic factor in N. Moreover, our results yield the best known bounds on the necessary embedding dimension m for a wide class of structured random matrices. In particular, for partial Fourier and partial Hadamard matrices, our method optimizes the dependence of m on the distortion δ : We improve the recent bound $m = O(\delta^{-4}\log(p)\log^4(N))$ of Ailon and Liberty (2010) to $m = O(\delta^{-2}\log(p)\log^4(N))$, which is optimal up to the logarithmic factors in N. Our results also have a direct application in the area of compressed sensing for redundant dictionaries.

– This is joint work with Rachel Ward.

Speaker: **Stefan Kunis** (University of Osnabrück)
Title: *Stability of sparse fast Fourier transforms*
Abstract: A straightforward discretization of high dimensional problems often leads to a serious growth in the number of degrees of freedom and thus even efficient algorithms like the fast Fourier transform have high computational costs. Utilizing sparsity allows for a severe decrease of the problem size but asks for the customization of efficient algorithms to these thinner discretization. We discuss two recent generalizations of the FFT: a hyperbolic cross FFT which is based on lattice rules and the so-called butterfly sparse FFT which is based on a multilevel approximation scheme.

– Joint work with T. Görner, L. Kämmerer, I. Melzer, and D. Potts.

Speaker: **Hassan Mansour** (University of British Columbia)
Title: *Weighted ℓ_1 Minimization: Stability, robustness, and some implications*
Abstract: We study the recovery conditions of weighted ℓ_1 minimization for signal reconstruction from

compressed sensing measurements when partial support information is available. Given a (partial) support estimate, we show that if at least 50% of this estimate is accurate, then weighted ℓ_1 minimization is stable and robust under conditions that are weaker than the analogous conditions for standard ℓ_1 minimization. Moreover, weighted ℓ_1 minimization provides better bounds on the reconstruction error in terms of the measurement noise and the compressibility of the signal to be recovered. We will illustrate our results with applications in real audio and video signals. We will also mention extensions of our results that lead to an iterative weighted ℓ_1 minimization algorithm that succeeds in recovering sparse signals when standard ℓ_1 minimization fails.

Speaker: **Deanna Needell** (Stanford University)
Title: *Acceleration of Randomized Kaczmarz Method via the Johnson-Lindenstrauss Lemma*
Abstract: The Kaczmarz method is an algorithm for finding the solution to an overdetermined system of linear equations Ax = b by iteratively projecting onto the solution spaces. The randomized version put forth by Strohmer and Vershynin yields provably exponential convergence in expectation, which for highly overdetermined systems even outperforms the conjugate gradient method. In this talk we present a modied version of the randomized Kaczmarz method which at each iteration selects the optimal projection from a randomly chosen set, which in most cases signi- cantly improves the convergence rate. We utilize a Johnson-Lindenstrauss dimension reduction technique to keep the runtime on the same order as the original randomized version, adding only extra preprocessing time. We present a series of empirical studies which demonstrate the remarkable acceleration in convergence to the solution using this modied approach.
– Joint work with Y. Eldar.

Speaker: **Ben Recht** (University of Wisconsin)
Title: The Convex Geometry of Linear Inverse Problems
Abstract: Building on the success of generalizing compressed sensing to matrix completion, this talk discusses progress on further extending the catalog of objects and structures that can be recovered from partial information. I will focus on a suite of data analysis algorithms designed to decompose signals into sums of atomic signals from a simple but not necessarily discrete set. These algorithms are derived in a convex optimization framework that encompasses previous methods based on l1-norm minimization and nuclear norm minimization for recovering sparse vectors and low-rank matrices. I will discuss general recovery guarantees and implementation schemes for this suite of algorithms and will describe several example classes of atoms and applications.
– Joint work with Venkat Chandrasekaran, Pablo Parrilo, and Alan Willsky

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

Speaker: **Rayan Saab** (University of British Columbia)
Title: *Sigma-Delta Quantization for Compressed Sensing*
Abstract: Compressed sensing, as a signal acquisition technique, has been shown to be highly effective for dimensionality reduction. However, in the digital era, signals must not only be sampled, but also quantized. The simplest and most commonly assumed approach for quantization of compressed sensing measurements involves using a uniform quantizer of step size δ to quantize m measurements $y = \Phi x$ of a

k-sparse signal $x \in \mathbb{R}^N$ (where Φ satisfies the restricted isometry property). In particular, the results of Candes, Romberg and Tao, and of Donoho guarantee that the reconstruction error via ℓ_1-minimization is $\mathcal{O}(\delta)$. Such a result is disappointing because the reconstruction error is not guaranteed to decrease as the number of compressed sensing measurements increases.

We show that if instead of uniform quantization, an rth order $\Sigma\Delta$ quantization scheme with the same output alphabet is used to quantize y, then there is an alternative recovery method via Sobolev dual frames which guarantees a reduction of the approximation error by a factor of $(m/k)^{(r-1/2)\alpha}$ for any $0 < \alpha < 1$, if $m \gtrsim_r k(\log N)^{1/(1-\alpha)}$. The result holds with high probability on the initial draw of the measurement matrix Φ from the Gaussian distribution, and uniformly for all k-sparse signals x that satisfy a mild size condition on their supports.

– Joint work with C.S. Güntürk, M. Lammers, A.M. Powell, Ö. Yılmaz

Speaker: **Mauricio Sacchi** (University of Alberta)
Title: *Application of sparse and rank reduction reconstruction to large-scale industrial seismic reconstruction problems*
Abstract: The problem of seismic data reconstruction has been tackled with a variety of signal processing methods. In general, seismic waveforms at observed spatial positions are expanded in terms of known basis functions and constrained inversion is utilized to estimate the coefficients of the expansion. The reconstruction is carried out by synthesizing data at unobserved spatial locations. Recent industrial applications in this area have demonstrated that it is possible to reconstruct 5D highly decimated seismic data cubes. This opens the possibility of decreasing sampling artifacts, acquisition costs and environmental footprints. Today data reconstruction is an integral part of seismic data preprocessing prior to imaging (migration). This talk will discuss MWNI (Minimum Weighted Norm Interpolation), an efficient method for wavefield reconstruction that has become the current standard for industrial applications of 5D data reconstruction (1-2). We will also discuss the connection of MWNI to reconstruction via sparse inversion of the Fourier coefficients. The last part of the talk will be devoted to new advances in data reconstruction. In particular, I will discuss reconstruction of large seismic volumes via rank reduction methods (3-5). I will stress how one can pose seismic data reconstruction as a tensor completion problem and examine different strategies for efficient industrial-strength algorithms for reconstructing extremely sparse multi-dimensional seismic data.

1. Liu, B. and Sacchi, M., 2004, Minimum Weighted Norm Interpolation of Seismic Records: Geophysics 69, 6.

2. Trad, D., 2009, Five Dimensional Interpolation: Geophysics, 60, V123-V32

3. Kreimer N. and Sacchi M., 2011, 5D Seismic volume reconstruction using HO-SVD: EAGE Vienna, Expanded abstracts.

4. Kreimer N. and Sacchi M., 2011, Evaluation of a new 5D seismic volume reconstruction method: Tensor completion versus Fourier reconstruction: CSEG Calgary, Expanded Abstract.

5. Gao J., Oropeza V. and Sacchi M., 2011, Evaluation of a fast algorithm for the eigen-decomposition of large Block Toeplitz matrices with application to 5D seismic data interpolation: CSEG Calgary, Expanded Abstract.

Speaker: **Nathan Srebro** (Toyota Technological Institute at Chicago)
Title: *A Tale of Two Norms*
Abstract: There has been much interest in recent years in various ways of constraining the complexity of matrices based on factorizations into a product of two simpler matrices. Such measures of matrix complexity can then be used as regularizers for such tasks as matrix completion, collaborative filtering, multi-task learning and multi-class learning. In this talk I will discuss two forms of matrix regularization which constrain the norm of the factorization, namely the trace-norm (aka nuclear-norm) and the so-called max-norm (aka $\gamma_2 : \ell_1 \to \ell_\infty$ norm). I will both argue that they are independently motivated and often better model data then rank constraints, as well as explore their relationships to the rank. In particular, I will discuss how simple low-rank matrix completion guarantees can be obtained using these measures,

and without various "incoherence" assumptions. I will present both theoretical and empirical arguments for why the max-norm might actually be a better regularizer, as well as a better convex surrogate for the rank.

– Based on joint work with Rina Foygel, Jason Lee, Ben Recht, Russ Salakhutdinov, Adi Shraibman and Joel Tropp.

Speaker: **Jean-Luc Starck** (Service d'Astrophysique CEA/Saclay)
Title: *Sparse analysis of the PLANCK cosmic microwave background data*
Abstract: Cosmic Microwave Background (CMB) temperature anisotropies and polarisation measurements have been one of the key cosmological probes to establish the current cosmological model. The ESA's PLANCK mission is designed to deliver full-sky coverage, low-noise level, high resolution temperature and polarisations maps. We will briefly review some of the key problem of the PLANCK data analysis, and we will present how sparsity can be used to analyze such data set.

Speaker: **Thomas Strohmer** (UC Davis)
Title: *Compressive Sensing - The Best or the Worst of Two Worlds?*
Abstract: Using Sparse MIMO Radar as case study I will analyze the potential benefits and pitfalls of Compressive Sensing, which finds itself caught between two extremes - the parametric and the non-parametric world. At first glance the benefits of Sparse MIMO Radar seem obvious, but a more careful analysis points to a conundrum and raises some challenging questions. Which of these questions have satisfactory answers?

Speaker: **V.N. Temlyakov** (University of South Carolina)
Title: *Lebesgue type inequalities for greedy approximation*
Abstract: While the ℓ_1 minimization technique plays an important role in designing computationally tractable recovery methods in compressed sensing, its complexity is still impractical for many applications. An attractive alternative to the ℓ_1 minimization is a family of greedy algorithms. We will discuss some greedy algorithms from the point of view of their theoretical performance. We will discuss Lebesgue type inequalities for greedy algorithms in both Hilbert and Banach spaces. By the Lebesgue type inequality we mean an inequality that provides an upper estimate for the error of a particular method of approximation of f by elements of a special form, say, form $\mathcal{A}$, by the best-possible approximation of f by elements of the form $\mathcal{A}$.

Speaker: **Jan Vybíral** (RICAM Linz)
Title: *Learning Functions of Few Arbitrary Linear Parameters in High Dimensions*
Abstract: We study the uniform approximation of a d-dimensional function f of the form $f(x) = g(Ax)$, where A is a $k \times d$ matrix and g is a function of k variables for $k \ll d$. We assume, that we are allowed to use only a limited number of function values of f. We start with the special cases, when $f(x) = f(x_1, \dots, x_d) = g(x_{i_1}, \dots, x_{i_k})$ or $f(x) = g(a \cdot x)$, where $a \in \mathbb{R}^d$ is a given vector, but the general case is addressed as well. We present a randomized algorithm based on a random choice of the sampling points x^j. We show that (under some restrictions on g and A) the algorithm gives a uniform approximation of f with high probability.

– Joint work with Massimo Fornasier and Karin Schnass