SampTA 2019

13th International conference on Sampling Theory and Applications

université de BORDEAUX

July 8-12

SampTA 2019

Time-table and abstracts

Acknoledgements

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Monday July 8, 9.15-12.30

Wegener	9.15-9.25	Opening address by Guy Melançon
Wegener	9.25-10.25	*Signal processing on graphs for applications in machine learning and network science* Pierre Vandergheynst

Compressed Sensing and low-rank matrix recovery (invited session)
Chair: Felix Kramer & Richard Kueng

Wegener	10.25-10.50	*Matrix Completion with Selective Sampling* Christian Parkinson, Kevin Huynh & Deanna Needell
Wegener	10.50-11.15	*Entropy Estimates on Tensor Products of Banach Spaces and Applications to Low-Rank Recovery* Kiryung Lee, Rakshith Sharma Srinivasa, Marius Junge & Justin K. Romberg
Wegener	11.15-11.40	*New Algorithms and Improved Guarantees for One-Bit Compressed Sensing on Manifolds* Rayan Saab, Mark Iwen, Eric Lybrand & Aaron Nelson
Wegener	11.40-12.05	*Matrix Completion with Selective Sampling** Christian Kümmerle & Cláudio M. Verdun
Wegener	12.05-12.30	*Robust Recovery of Sparse Non-negative Weights from Mixtures of Positive-Semidefinite Matrices** Peter Jung

Gabor Analysis

Edison	10.25-10.50	*Signal transmission through an unidentified channel** Dae Gwan Lee, Goetz E Pfander & Volker Pohl
Edison	10.50-11.15	*A quantitative Balian-Low theorem for subspaces* Andrei Caragea, Dae Gwan Lee, Friedrich Philipp & Felix Voigtlaender
Edison	11.15-11.40	*Time-Frequency Shift Invariance of Gabor Spaces* Friedrich Philipp, Andrei Caragea, Dae Gwan Lee & Felix Voigtlaender
Edison	11.40-12.05	*Adaptive Frames from Quilted Local Time-Frequency Systems* Arvin Lamando & Gino Angelo Velasco
Edison	12.05-12.30	*On the smoothness of dual windows for Gabor windows supported on* $[-1;1]$ * Kamilla H. Nielsen & Jakob Lemvig

Monday July 8, 14.00-18.00

Wegener	14.00-15.00	*Combinatorial compressed sensing with expanders* Alexandre d'Aspremont

Frame Theory (invited session)
Chair: John Jasper & Dustin Mixon

Wegener	15.00-15.25	*Equi-isoclinic subspaces from difference sets* Matthew Fickus & Courtney Schmitt
Wegener	15.25-15.50	*Exact Line Packings from Numerical Solutions* Hans Parshall & Dustin G. Mixon
Wegener	15.50-16.15	*2- and 3-Covariant Equiangular Tight Frames* Emily King
Wegener	16.15-16.45	*Coffee Break*
Wegener	16.45-17.10	*The Zak transform and representations induced from characters of an abelian subgroup* Joseph W. Iverson
Wegener	17.10-17.35	*A Delsarte-Style Proof of the Bukh-Cox Bound* Mark E. Magsino, Dustin G. Mixon & Hans Parshall

Phase retrieval

Edison	15.00-15.25	*Conjugate Phase Retrieval in Paley-Wiener Space* Eric S. Weber, Friedrich Littmann & Chun-Kit Lai
Edison	15.25-15.50	*Phase Retrieval for Wide Band Signals* Philippe Jaming, Karim Kellay & Rolando Perez III
Edison	15.50-16.15	*Dual-Reference Design for Holographic Phase Retrieval* David A Barmherzig, Ju Sun, Emmanuel Candès, Thomas Joseph Lane & Po-Nan Li
	4.15-45	*Coffee Break*

Probabilistic Methods

Edison	16.45-17.10	*Non-Gaussian Random Matrices on Sets: Optimal Tail Dependence and Applications* Halyun Jeong, Xiaowei Li, Yaniv Plan & Ozgur Yilmaz
Edison	17.10-17.35	*Fast Multitaper Spectral Estimation* Santhosh Karnik, Justin K Romberg & Mark Davenport
Edison	17.35-18.00	*Monte Carlo wavelets: a randomized approach to frame discretization* Stefano Vigogna, Zeljko Kereta, Valeriya Naumova, Lorenzo Rosasco & Ernesto De Vito

Tuesday July 9, 8.30-12.10

Wegener	8.30-9.30	*Metric repair on manifolds with holes* Anna Gilbert
	9.30-10	*Coffee Break*

Time-frequency analysis (invited session)
Chair: Antti Haimi & José Luis Romero

A9 - Amphi 1	10.05-10.30	*The Strohmer and Beaver Conjecture for Gaussian Gabor Systems - A Deep Mathematical Problem (?)* Markus Faulhuber
	10.30-10.55	*Scaling limits in planar eigenvalue ensembles* Yacin Ameur
	10.55-11.20	*A correspondence between zeros of time-frequency transforms and Gaussian analytic functions* Rémi Bardenet, Pierre Chainais, Julien Flamant & Adrien Hardy
	11.20-11.45	*The Diamond ensemble: a well distributed family of points on $\mathbb{S}^2$* Carlos Beltrán & Ujué Etayo
	11.45-12.10	*Filtering the Continuous Wavelet Transform Using Hyperbolic Triangulations* Günther Koliander, Luís Daniel Abreu, Antti Haimi, José Luis Romero

Tuesday July 9, 8.30-12.10

Compressed sensing

A9 Amphi 2

10.05-10.30	*Multiplication-free coordinate descent iteration for ℓ^1-regularized least squares* Nguyen T. Thao & Dominik Rzepka	
10.30-10.55	*Random Gabor Multipliers and Compressive Sensing* Georg Tauböck, Shristi Rajbamshi, Peter Balazs & Luís Daniel Abreu	
10.55-11.20	*Parameter Instability Regimes in Sparse Proximal Denoising Programs* Aaron Berk, Yaniv Plan & Ozgur Yilmaz	
11.20-11.45	*Phase transition for eigenvalues and recovery of rank one matrices* Enrico Au-Yeung & Greg Zanotti	
11.45-12.10	*Sparse synthesis regularization with deep neural networks* Daniel Obmann, Markus Haltmeier & Johannes Schwab	

Deep learning

A9 - Amphi 3

10.05-10.30	*Projection-Based 2.5D U-net Architecture for Fast Volumetric Segmentation* Christoph H. Angermann & Markus Haltmeier	
10.30-10.55	*Unfavorable structural properties of the set of neural networks with fixed architecture* Philipp Petersen, Mones Raslan & Felix Voigtlaender	
10.55-11.20	*Towards a Regularity Theory for ReLU Networks* Dennis Elbrächter, Julius Berner, Philipp Grohs & Arnulf Jentzen	
11.20-11.45	*A Rate-Distortion Framework for Explaining Deep Neural Network Decisions* Stephan Wäldchen, Jan Macdonald, Sascha Hauch & Gitta Kutyniok	
11.45-12.10	*Deep-Sparse Array Cognitive Radar* Ahmet M. Elbir, Satish Mulleti, Regev Cohen, Rong Fu & Yonina C. Eldar	

Tuesday July 9, 14.45-20.00

Wegener	13.45-14.45	*Combinatorial compressed sensing with expanders* Bubacarr Bah

Deep learning (invited session)
Chair: Misha Belkin & Mahdi Soltanolkotabi

A9 Amphi 1	14:55-15:20	*Reconciling modern machine learning practice and the classical bias-variance trade-off* Mikhail Belkin, Daniel Hsu, Siyuan Ma & Soumik Mandal
	15.20-15.45	*Overparameterized Nonlinear Optimization with Applications to Neural Nets* Samet Oymak
	15.45-16.10	*General Bounds for 1-Layer ReLU approximation* Bolton R. Bailey & Matus Telgarsky
	4.10-4.20	Short Break
	16.20-16.45	*Generalization in deep nets: an empirical perspective* Tom Goldstein
	16.45-17.10	*Neuron birth-death dynamics accelerates gradient descent and converges asymptotically* Joan Bruna

Frame Theory

A9 Amphi 2	14.55-15.20	*Banach frames and atomic decompositions in the space of bounded operators on Hilbert spaces* Peter Balazs
	15.20-15.45	*Frames by Iterations in Shift-invariant Spaces* Alejandra Aguilera, Carlos Cabrelli, Diana Carbajal & Victoria Paternostro
	15.45-16.10	*Frame representations via suborbits of bounded operators* Ole Christensen & Marzieh Hasannasabjaldehbakhani
	16.10-16.20	Short Break
	16.20-16.45	*Sum-of-Squares Optimization and the Sparsity Structure of Equiangular Tight Frames* Dmitriy Kunisky & Afonso Bandeira
	16.45-17.10	*Frame Potentials and Orthogonal Vectors* Josiah Park
	17.10-17.35	*Compactly Supported Tensor Product Complex Tight Framelets with Directionality* Xiaosheng Zhuang & Bin Han

Tuesday July 9, 14.45-20.00

Phase retrieval

A9 Amphi 3	14.55-15.20	*Phase Estimation from Noisy Data with Gaps* Yitong Huang, Clark Bowman, Olivia Walch & Daniel Forger
A9 Amphi 3	15.20-15.45	*Phase retrieval from local correlation measurements with fixed shift length* Oleh Melnyk, Frank Filbir & Felix Krahmer
A9 Amphi 3	15.45-16.10	*Ill-conditionedness of discrete Gabor phase retrieval and a possible remedy* Matthias Wellershoff & Rima Alaifari
	16.10-16.20	Short break

Quantization

A9 Amphi 3	16.20-16.45	*Higher order 1-bit Sigma-Delta modulation on a circle* Olga Graf, Felix Krahmer & Sara Krause-Solberg
A9 Amphi 3	16.45-17.10	*One-Bit Compressed Sensing Using Smooth Measure of ℓ^0 Norm* Sina Alemohammad & Arash Amini
	17.45-20.00	**Poster simposio** Domaine du Haut-Carré

Wednesday July 10, 8.30-12.05 am

Wegener	8.30-9.30	*Approximation by crystal invariant subspaces* Ursula Molter
Wegener	9.30-10	*Coffee Break*

Phase Retrieval (invited session)

A9 Amphi 1	10.05-10.30	*3D Phaseless Imaging at Nano-scale: Challenges and Possible Solutions* Mahdi Soltanolkotabi
A9 Amphi 1	10.30-10.55	*Optimally Sample-Efficient Phase Retrieval with Deep Generative Models* Oscar Leong, Paul Hand & Vladislav Voroninski
A9 Amphi 1	10.55-11.20	*The Cramer-Rao Lower Bound in the Phase Retrieval Problem* Radu Balan & David Bekkerman
A9 Amphi 1	11.20-11.45	*Stability of the Phase Retrieval Problem* Palina Salanevich
A9 Amphi 1	11.45-12.10	*PhasePack: A Phase Retrieval Library* Tom Goldstein, Christoph Studer & Rohan Chandra

Non-Euclidean signal processing

A9 Amphi 2	10.05-10.30	*Generalized Sampling on Graphs With A Subspace Prior* Yuichi Tanaka & Yonina C. Eldar
A9 Amphi 2	10.30-10.55	*Numerical computation of eigenspaces of spatio-spectral limiting on hypercubes* Joseph Lakey & Jeffrey Hogan
A9 Amphi 2	10.55-11.20	*On the Transferability of Spectral Graph Filters* Ron Levie, Elvin Isufi & Gitta Kutyniok
A9 Amphi 2	11.20-11.45	*Sampling on Hyperbolic Surfaces* Stephen D. Casey
A9 Amphi 2	11.45-12.10	*Random Sampling for Bandlimited Signals on Product Graphs* Rohan Varma & Jelena Kovačević

14:00-19:00	**Excursion to St Émilion**

Thursday July 11, 8.30-12.05 am

Wegener	8.30-9.30	*Bagging the Peaks: Matrix and Tensor Factorization with Unimodal Constraints* Urbashi Mitra
Wegener	9.30-10	*Coffee Break*

Missing data imputation (invited session)

A9 Amphi 1	10.05-10.30	*Comparison of Imputation Methods for Race and Ethnic Information in Administrative Health Data* Ofer Harel, Yishu Xue & Robert Aseltine
A9 Amphi 1	10.30-10.55	*Adaptive sequential regression imputation methods using machine learning techniques* Trivellore E. Raghunathan
A9 Amphi 1	10.55-11.20	*Tractable Learning of Sparsely Used Dictionaries from Incomplete Sample* Thanh Nguyen, Akshay Soni & Chinmay Hegde
A9 Amphi 1	11.20-12.10	*Panel discussion*

Fourier analysis and sampling

A9 Amphi 2	10.05-10.30	*Sampling over spiraling curves* Philippe Jaming, Felipe Negreira & José Luis Romero
A9 Amphi 2	10.30-10.55	*Time encoding and perfect recovery of non-bandlimited signals with an integrate-and-fire system* Roxana Alexandru & Pier Luigi Dragotti
A9 Amphi 2	10.55-11.20	*Optimal Spline Generators for Derivative Sampling* Shayan Aziznejad, Alireza Naderi & Michael Unser
A9 Amphi 2	11.20-11.45	*On cosine operator function framework of windowed Shannon sampling operators* Andi Kivinukk, Olga Graf & Anna Saksa
A9 Amphi 2	11.20-12.10	*On Identifiability in Unlimited Sampling* Ayush Bhandari & Felix Krahmer

Thursday July 11, 13.45-23.00

Wegener	13.45-14.45	*Lyapunov's theorem and sampling of continuous frames* Marcin Bownik

Graph signal processing (invited session)
Chair: Karlheinz Gröchenig & Isaac Pesenson

A9 Amphi 1	14:50-15:15	*Sampling and reconstruction of graph signals: An overview of recent graph signal processing results* António G. Marques
	15.15-15.40	*Iterative Chebyshev Polynomial Algorithm for Signal Denoising on Graphs* Cheng Cheng, Junzheng Jiang, Nazar Emirov & Qiyu Sun
	15.04-16.05	*A non-commutative viewpoint on graph signal processing* Mahya Ghandehari, Dominique Guillot & Kristopher Hollingsworth
	16.05-16.30	*Coffee Break*
	16.30-16.55	*Clustering on Dynamic Graphs based on Total Variation* Peter Berger, Thomas Dittrich & Gerald Matz
	16.55-17.20	*Enabling Prediction via Multi-Layer Graph Inference and Sampling* Stefania Sardellitti, Sergio Barbarossa & Paolo Di Lorenzo
	17.20-17.45	*Blue-Noise Sampling of Signals on Graphs* Alejandro Parada, Daniel Lau, Jhony Giraldo & Gonzalo Arce
	17.45-18.10	*Average sampling, average splines and Poincaré inequality on combinatorial graphs* Isaac Pesenson

Thursday July 11, 13.45-23.00

Wavelets, Shearlets,...

A9 Amphi 2

14:50-15:15	*Higher-dimensional wavelets and the Douglas-Rachford algorithm* Jeffrey Hogan, David Franklin & Matthew Tam	
15.15-15.40	*Analytic and directional wavelet packets* Valery Zheludev	
15.40-16.05	*Optimization in the construction of nearly cardinal and nearly symmetric wavelets* Neil Dizon, Jeffrey Hogan & Joseph Lakey	
16.05-16.30	*Coffee Break*	
16.30-16.55	*Monte Carlo wavelets: a randomized approach to frame discretization* Stefano Vigogna, Zeljko Kereta, Valeriya Naumova, Lorenzo Rosasco & Ernesto De Vito	
16.55-17.20	*Analysis of shearlet coorbit spaces in arbitrary dimensions using coarse geometry* René Koch & Hartmut Führ	
17.20-17.45	*Trace Result of Shearlet Coorbit Spaces on Lines* Qaiser Jahan, Stephan Dahlke & Gabriele Steidl	

Thursday July 11, 13.45-23.00

Super-Resolution

A9 Amphi 3

14:50-15:15	*The dual approach to non-negative super-resolution: impact on primal reconstruction accuracy* Bogdan Toader, Stéphane Chrétien & Andrew Thompson
15.15-15.40	*Conditioning of restricted Fourier matrices and super-resolution of MUSIC* Wenjing Liao & Weilin Li
15.04-16.05	*Iterative Discretization of Optimization Problems Related to Superresolution* Axel Flinth & Pierre Armand Weiss
16.05-16.30	*Coffee Break*

Sampling and Fourier analysis

A9 Amphi 3

16.30-16.55	*On the Reconstruction of a Class of Signals Bandlimited to a Disc* Ahmed Zayed
16.55-17.20	*The Solvability Complexity Index of Sampling-based Hilbert Transform Approximations* Volker Pohl & Holger Boche
17.20-17.55	*The Convolution Word is Tied to the Exponential Kernel Transforms. What is a Parallel Expression for the Other Transforms?* Abdul Jerri
19.30-23.00	**Conference dinner** Café du Port 1 Quai Deschamps, 33100 Bordeaux

Friday July 12, 8.30-12.05

Wegener	8.30-9.30	*Robust and efficient identification of neural networks* Massimo Fornasier
	9.30-10	*Coffee Break*

Quantization (invited session)
Chair: Sjoerd Dirksen & Rayan Saab

Wegener	10.00-10.25	*Robust One-bit Compressed Sensing With Manifold Data* Mark Iwen, Sjoerd Dirksen, Johannes Maly & Sara Krause-Solberg
	10.25-10.50	*One-Bit Sensing of Low-Rank and Bisparse Matrices* Simon Foucart & Laurent Jacques
	10.50-11.15	*Robust 1-Bit Compressed Sensing via Hinge Loss Minimization* Alexander Stollenwerk & Martin Genzel
	11.15-11.40	*High-performance quantization for spectral super-resolution* Sinan Gunturk & Weilin Li
	11.40-12.05	*On one-stage recovery for $\Sigma\Delta$-quantized compressed sensing* Ozgur Yilmaz & Arman Ahmadieh

Fourier analysis

Edison	10.00-10.25	*Riesz bases of exponentials for partitions of intervals* David Walnut, Goetz E. Pfander & Shauna Revay
	10.25-10.50	*Computability of the Fourier Transform and ZFC* Holger Boche & Ullrich J. Mönich
	10.50-11.15	*Rearranged Fourier Series and Generalizations to Non-Commutative Groups* Armenak Petrosyan, Keaton Hamm & Benjamin Hayes
	11.15-11.40	*Deterministic guarantees for L^1-reconstruction: A large sieve approach with geometric flexibility* Michael Speckbacher & Luís Daniel Abreu
	11.40-12.05	*A Clifford Construction of Multidimensional Prolate Spheroïdal Wave Functions* Hamed Baghal Ghaffari, Jeffrey Hogan & Joseph Lakey

Friday July 12, 13.30-15.35

Deep Learning

Wegener	13.30-13.55	*Approximation in $L^p(\mu)$ with deep ReLU neural networks* Felix Voigtlaender & Philipp Petersen
Wegener	13.55-14.20	*Modeling Global Dynamics from Local Snapshots with Deep Generative Neural Networks* Scott Gigante, David Van Dijk, Kevin Moon, Alexander Strzalkowski, Guy Wolf & Smita Krishnaswamy

Inverse problems

Edison	13.30-13.55	*Convergence Rates for Hölder-Windows in Filtered Back Projection* Matthias Beckmann & Armin Iske
Edison	13.55-14.20	*Dynamical Sampling with a Burst-like Forcing Term* Akram Aldroubi, Longxiu Huang, Keri Kornelson & Ilya Krishtal

Wegener	14.30-15.30	*Learning from moments - Large-scale learning with the memory of a goldfish* Rémi Gribonval
Wegener	15.30-15.35	*Closing*

Monday Morning.

09:15 - 10:15 A22 - Wegener: Pierre Vandergheynst.

Signal processing on graphs for applications in machine learning and network science

10.25-12.30 A22 - Wegener: Compressed Sensing and low-rank matrix recovery. 10.25-10.50: Matrix Completion with Selective Sampling

Christian Parkinson, Kevin Huynh & Deanna Needell

Abstract: Matrix completion is a classical problem in data science wherein one attempts to reconstruct a low-rank matrix while only observing some subset of the entries. Previous authors have phrased this problem as a nuclear norm minimization problem. Almost all previous work assumes no explicit structure of the matrix and uses uniform sampling to decide the observed entries. We suggest methods for selective sampling in the case where we have some knowledge about the structure of the matrix and are allowed to design the observation set.

10.50-11.15: Entropy Estimates on Tensor Products of Banach Spaces and Applications to Low-Rank Recovery

Kiryung Lee, Rakshith Sharma Srinivasa, Marius Junge & Justin K. Romberg

Abstract: Low-rank matrix models have been universally useful for numerous applications starting from classical system identification to more modern matrix completion in signal processing and statistics. The Schatten-1 norm, also known as the nuclear norm, has been used as a convex surrogate of the low-rankness since it induces a low-rank solution to inverse problems. While the Schatten-1 norm for low-rankness has a nice analogy with the ℓ^1 norm for sparsity through the singular value decomposition, other matrix norms also induce low-rankness. Particularly as one interprets a matrix as a linear operator between Banach spaces, various tensor product norms generalize the role of the Schatten-1 norm. Inspired by a recent work on the max-norm based matrix completion, we provide a unified view on a class of tensor product norms and their interlacing relations on low-rank operators. Furthermore we derive entropy estimates between the injective and projective tensor products of a family of Banach space pairs and demonstrate their applications to matrix completion and decentralized subspace sketching.

11.15-11.40: New Algorithms and Improved Guarantees for One-Bit Compressed Sensing on Manifolds

Rayan Saab, Mark Iwen, Eric Lybrand & Aaron Nelson

Abstract: We study the problem of approximately recovering signals on a manifold from one-bit linear measurements drawn from either a Gaussian ensemble, partial circulant ensemble, or bounded orthonormal ensemble and quantized using $\Sigma\Delta$ or distributed noise shaping schemes. We assume we are given a Geometric Multi-Resolution Analysis, which approximates the manifold, and we propose a convex optimization algorithm for signal recovery. We prove an upper bound on the recovery error which outperforms prior works that use memoryless scalar quantization, requires a simpler analysis, and extends the class of measurements beyond Gaussians. Finally, we illustrate our results with numerical experiments.

11.40-12.05: Matrix Completion with Selective Sampling

Christian Kümmerle & Cláudio M. Verdun

Abstract: We propose a new Iteratively Reweighted Least Squares (IRLS) algorithm for the problem of completing a low-rank matrix that is linearly structured, e.g., that possesses a Hankel, Toeplitz or block-Hankel/ Toeplitz structures, which is of relevance for the harmonic retrieval or super-resolution problem. The algorithm optimizes a non- convex surrogate of the rank by minimizing well-chosen quadratic upper bounds of the smoothed surrogate. We establish a quadratic local convergence rate of the developed IRLS strategy if the linear structure is Hankel, with high probability if the provided entries of the matrix are sampled uniformly at random, and if the matrix to be completed fulfills a suitable coherence condition. Our strategy combines computational efficiency, as the dimensionality of its optimization variables scales sub-linearly in the matrix dimensions, with a favorable data efficiency, as it can be observed in experiments on hard completion tasks. In particular, our experiments show that the proposed algorithm exhibits an empirical recovery probability close to one from fewer samples than existing state-of-the-art approaches for the Hankel matrix completion task arising from the problem of spectral super-resolution of frequencies with small separation.

12.05-12.30: Robust Recovery of Sparse Non-negative Weights from Mixtures of Positive-Semidefinite Matrices

Peter Jung

Abstract: We consider a model where a matrix is generated as an s-sparse linear combination of d given $n \times n$ positive-semidefinite matrices. Recovering the unknown d-dimensional and s-sparse weights from noisy observations is an important problem in various fields of signal processing and also a relevant pre-processing step in covariance estimation. We will present related recovery guarantees and focus on the case of non-negative weights. The problem is formulated as a convex program and can be solved without further tuning. Such robust, non-Bayesian and parameter-free approaches are important for applications where prior distributions and further model parameters are unknown.

We will discuss some applications in wireless communication like estimating (non-negative) pathloss coefficients and user activity using multiple antennas. Here, a small subset of s¡¡d devices indicate activity by transmitting specific length-n sequences which superimpose at each receive antenna with individual and unknown instantaneous channel coefficients. Well-known results in compressed sensing show that when using for given s and d sufficiently random sequences of length $n = O(s\,\mathrm{polylog}(d))$ one can recover per antenna w.h.p. the channel coefficients and the activity pattern (the essential support). However, since in future even s will grow considerably the question is how to further gain from a massive number of receive antennas.

We will present some recent ideas and scaling laws in this context. In particular, using the analysis above for the rank-one case, for given n and d one can recover pathloss coefficients and activity of up to $s = n^2/\mathrm{polylog}(d/n^2)$ devices from the empirical covariance over sufficiently many receive antennas.

10.25-12.30 A22 - Edison: Gabor Analysis. 10.25-10.50: Signal transmission through an unidentified channel

Dae Gwan Lee, Goetz E Pfander & Volker Pohl

Abstract: We formulate and study the problem of recovering a signal x in $\mathcal{X} \subset \mathbb{C}^L$ which, after adding with a signal $c \in \mathbb{C}^L \setminus \{0\}$, is transmitted through an unknown channel H in $\mathcal{H} \subset \mathcal{L}(\mathbb{C}^L, \mathbb{C}^L)$. Here, $\mathcal{X}$ and $\mathcal{H}$ are a priori known and fixed while c is designed by the user. In particular, we focus on the case where $\mathcal{H}$ is generated by a subset of time-frequency shift operators on $\mathbb{C}^L$, which leads to investigation of properties of Gabor matrices.

10.50-11.15: A quantitative Balian-Low theorem for subspaces

Andrei Caragea, Dae Gwan Lee, Friedrich Philipp & Felix Voigtlaender

Abstract: We consider Gabor Riesz sequences generated by a window function with finite uncertainty product over a rational lattice in $\mathbb{R}^2$. We prove that the distance of a time-frequency shift of the window function to the Gabor space is equivalent, up to constants, to the Euclidean distance of the parameters of the time- frequency shift to the lattice. Under certain additional assumptions, these constants can be estimated. As a byproduct of the methods employed, we also obtain a strengthening of the so-called weak Balian-Low theorem.

11.15-11.40: Time-Frequency Shift Invariance of Gabor Spaces

Friedrich Philipp, Andrei Caragea, Dae Gwan Lee & Felix Voigtlaender

Abstract: We consider non-complete Gabor frame sequences generated by an S_0-function and a lattice Λ and prove that there is $m \in \mathbb{N}$ such that all time-frequency shifts leaving the corresponding Gabor space invariant have their parameters in $\frac{1}{\Lambda}$. We also investigate time-frequency shift invariance under duality aspects.

11.40-12.05: Adaptive Frames from Quilted Local Time-Frequency Systems

Arvin Lamando & Gino Angelo Velasco

Abstract:

A family of regions that cover the time-frequency plane is considered, and from each region, (possibly irregular) sampling points are taken, thereby generating local time-frequency systems for each component region. This results to "local patches" of Gabor systems which are then put together. In this work, we will be looking at different conditions in which the resulting quilted system, as well as its projection onto subspaces of eigenfunctions of time-frequency localization operators, is to exhibit a frame property.

12.05-12.30: On the smoothness of dual windows for Gabor windows supported on $[-1;1]$

Kamilla H. Nielsen & Jakob Lemvig

Abstract: We study Gabor frames of the form $\{e^{2\pi ibm\cdot}g(\cdot - ak)\}_{m,k\in\mathbb{Z}}$ generated by windows $g \in C^n(\mathbb{R})$, $n \in \mathbb{Z}_{\geq 0} \cup \{\infty\}$, that are (only) non-zero on an open interval of length $L > 0$ with translation parameter $a = L/2$ and modulation parameter $b \in (0, 2/L)$. We review a recent explicit construction of all dual windows with sufficiently short support by the two authors [J. Lemvig, K. H. Nielsen, Gabor windows supported on $[-1, 1]$ and construction of compactly supported dual windows with optimal frequency localization, preprint]. We then show that the obtainable smoothness index m in $C^m(\mathbb{R})$ of dual windows depends on the location of singularities of g, e.g., on the location of points x_0, where $g^{(m)}(x_0)$ fails to be continuous for $m > n$. Our proof yields an explicit construction procedure of smooth dual windows once the singularities of g avoid the specified locations.

Monday Afternoon.

14:00 - 15:00 A22 - Wegener: Alexandre d'Aspremont.

Sharpness, Restart and Compressed Sensing Performance

Abstract: We show that several classical quantities controlling compressed sensing performance directly match parameters controlling algorithmic complexity. We first describe linearly convergent restart schemes on first-order methods using a sharpness assumption. The Lojasievicz inequality shows that sharpness bounds on the minimum of convex optimization problems hold almost generically. Here, we show that sharpness directly controls the performance of restart schemes. For sparse recovery problems, sharpness at the optimum can be written as a condition number, given by the ratio between true signal sparsity and the largest signal size that can be recovered by the observation matrix. Overall, this means that in compressed sensing problems, a single parameter directly controls both computational complexity and recovery performance.

Joint work with Vincent Roulet (University of Washington) and Nicolas Boumal (Princeton University).

15:00 - 17:35 A22 - Wegener: Frame theory. 15:00-15:25: Equi-isoclinic subspaces from difference sets

Matthew Fickus & Courtney Schmitt

Abstract: Equi-chordal tight fusion frames (ECTFFs) and equi-isoclinic tight fusion frames (EITFFs) are types of optimal packings in Grassmannian spaces. In particular, an ECTFF is an arrangement of equi-dimensional subspaces of a Euclidean space with the property that the smallest chordal distance between any pair of these subspaces is as large as possible. An EITFF is a special type of ECTFF that also happens to be an optimal packing with respect to the spectral distance. In the special case where the subspaces are one-dimensional, both ECTFFs and EITFFs reduce to optimal packings of lines known as equiangular tight frames (ETFs); these lines have minimal coherence, achieving equality in the Welch bound. ETFs are tricky to construct, but several infinite families of them are known. Harmonic ETFs in particular arise by restricting the characters of a finite abelian group to a difference set for that group. Moreover, there is a simple tensor-based method for combining ETFs with orthonormal bases to form EITFFs. It is an open question as to whether every EITFF essentially arises in this way. In this short paper, we preview a new result relating difference sets, harmonic ETFs, ECTFFs and EITFFs. This work expands on other recent results showing that certain harmonic ETFs are comprised of a number of simpler ETFs known as regular simplices; such ETFs arise, for example, from McFarland difference sets as well as the complements of certain Singer difference sets. It is already known that in this situation the subspaces spanned by these regular simplices necessarily form an ECTFF. We recently discovered that these same subspaces form an EITFF in some, but not all, cases. In an upcoming journal article, we shall characterize the properties of the underlying difference sets that lead to EITFFs in this fashion.

15:25-15:50: Exact Line Packings from Numerical Solutions

Hans Parshall & Dustin G. Mixon

Abstract: Recent progress in Zauner's conjecture has leveraged deep conjectures in algebraic number theory to promote numerical line packings to exact and verifiable solutions to the line packing problem. We introduce a numerical-to-exact technique in the real setting that does not require such conjectures. Our approach is completely reproducible, matching

Sloane's database of putatively optimal numerical line packings with Mathematica's built-in implementation of cylindrical algebraic decomposition. As a proof of concept, we promote a putatively optimal numerical packing of eight points in the real projective plane to an exact packing, whose optimality we establish in a forthcoming paper.

15:50 - 16:15: 2- and 3-Covariant Equiangular Tight Frames

Emily King

Abstract: Equiangular tight frames (ETFs) are configurations of vectors which are optimally geometrically spread apart and provide resolutions of the identity. Many known constructions of ETFs are group covariant, meaning they result from the action of a group on a vector, like all known constructions of symmetric, informationally complete, positive operator-valued measures. In this short article, some results characterizing the transitivity of the symmetry groups of ETFs will be presented as well as a proof that an infinite class of so-called Gabor-Steiner ETFs are roux lines, where roux lines are a generalization of doubly transitive lines.

16:45-17:10: The Zak transform and representations induced from characters of an abelian subgroup

Joseph W. Iverson

Abstract: We introduce a variant of the Zak transform for a finite group G with respect to a fixed abelian subgroup H, and demonstrate a relationship with representations of G induced from characters of H. We also show how the Zak transform can be used to study right translations by H in $L^2(G)$, and give some examples of applications for equiangular tight frames.

17:10-17:35: A Delsarte-Style Proof of the Bukh-Cox Bound

Mark E. Magsino, Dustin G. Mixon & Hans Parshall

Abstract: The line packing problem is concerned with the optimal packing of points in real or complex projective space so that the minimum distance between points is maximized. Until recently, all bounds on optimal line packings were known to be derivable from Delsarte's linear program. Last year, Bukh and Cox introduced a new bound for the line packing problem using completely different techniques. In this paper, we use ideas from the Bukh-Cox proof to find a new proof of the Welch bound, and then we use ideas from Delsarte's linear program to find a new proof of the Bukh-Cox bound. Hopefully, these unifying principles will lead to further refinements.

15:00 - 16:15 A22 - Edison: Phase retrieval. 15.00-15.25: Conjugate Phase Retrieval in Paley-Wiener Space

Eric S. Weber, Friedrich Littmann & Chun-Kit Lai

Abstract: We consider the problem of conjugate phase retrieval in Paley-Wiener space PW_π. The goal of conjugate phase retrieval is to recover a signal f from the magnitudes of linear measurements up to unknown phase factor and unknown conjugate, meaning $f(t)$ and $\overline{f(t)}$ are not necessarily distinguishable from the available data. We show that conjugate phase retrieval can be accomplished in PW_π by sampling only on the real line by using structured convolutions. We also show that conjugate phase retrieval can be accomplished in PW_π by sampling both f and f' only on the real line. Finally, we show that generically, conjugate phase retrieval can be accomplished by sampling at 3 times the Nyquist rate, whereas phase retrieval requires sampling at 4 times the Nyquist rate.

15.25-15.50: Phase Retrieval for Wide Band Signals

Philippe Jaming, Karim Kellay & Rolando Perez III

Abstract: This study investigates the phase retrieval problem for wideband signals. More precisely, we solve the following problem: given $f \in L^2(\mathbb{R})$ with Fourier transform in $L^2(\mathbb{R}, e^{2c|x|}\mathrm{d}x)$ we determine all functions $g \in L^2(\mathbb{R})$ with Fourier transform in $L^2(\mathbb{R}, e^{2c|x|}\mathrm{d}x)$, such that $|f(x)| = |g(x)|$ for all $x \in \mathbb{R}$. To do so, we translate the problem into a phase retrieval problem for functions in Hardy spaces on the disc and use the ineer-outer factorization.

15.50-16.15: Dual-Reference Design for Holographic Phase Retrieval

David A Barmherzig, Ju Sun, Emmanuel Candès, Thomas Joseph Lane & Po-Nan Li

Abstract: A new reference design is introduced for Holographic Coherent Diffraction Imaging. This consists of two reference portions - being "block" and "pinhole" shaped regions - adjacent to the imaging specimen. Expected error analysis on data following a Poisson shot noise model shows that the dual-reference scheme produces smaller weighting of error across the frequency spectrum than does the leading single-reference schemes. Numerical experiments on simulated data also shows the dual-reference scheme achieving a smaller recovery error than the leading single-reference schemes.

16:45 - 17:35 A22 - Edison: Probabilistic Methods.

16.45-17.10: Non-Gaussian Random Matrices on Sets: Optimal Tail Dependence and Applications

Halyun Jeong, Xiaowei Li, Yaniv Plan & Ozgur Yilmaz

Abstract: Random linear mappings play a large role in modern signal processing and machine learning. For example, multiplication by a Gaussian matrix can preserve the geometry of a set while reducing the dimension. Non-gaussian random mappings are attractive in practice for several reasons, including improved computational cost. On the other hand, mappings of interest often have heavier tails than Gaussian, which can lead to worse performance, i.e., less accurate preservation of the geometry of the set. In the sub-Gaussian case, the size of the tail is measured with the sub-gaussian parameter, but the dependency has not been fully understood yet. We present the optimal dependency on the sub-gaussian parameter and prove it through a new version of Bernstein's inequality. We also illustrate popular applications whose theoretical guarantees can be improved by our results.

17.10-17.35: Fast Multitaper Spectral Estimation

Santhosh Karnik, Justin K Romberg & Mark Davenport

Abstract: Thomson's multitaper method using discrete prolate spheroidal sequences (DPSSs) is a widely used technique for spectral estimation. For a signal of length N, Thomson's method requires selecting a bandwidth parameter W, and then uses $K \sim 2NW$ tapers. The computational cost of evaluating the multitaper estimate at N grid frequencies is $O\big(KN\log(N)\big)$. It has been shown that the choice of W and K which minimizes the MSE of the multitaper estimate is $W = O(N^{-1/5})$ and $K = O(N^{4/5})$. This choice would require a computational cost of $O\big(N^{9/5}\log(N)\big)$. We demonstrate an ε-approximation to the multitaper estimate which can be evaluated at N grid frequencies using $O\big(N\log^2(N)\log(1/\varepsilon)\big)$ operations.

17.35-18.00: Monte Carlo wavelets: a randomized approach to frame discretization

Stefano Vigogna, *Zeljko Kereta*, Valeriya Naumova, Lorenzo Rosasco & Ernesto De Vito

Abstract: In this paper we propose and study a family of continuous wavelets on general domains, and a corresponding stochastic discretization that we call Monte Carlo wavelets. First, using tools from the theory of reproducing kernel Hilbert spaces and associated integral operators, we define continuous wavelets using spectral calculus. Then, we propose a stochastic discretization based on Monte Carlo estimates of the integral operators. Using concentration of measure results, we establish the convergence of such a discretization and derive convergence rates under natural regularity assumptions.

Tuesday Morning.

8:30 - 9:30 A22 - Wegener: Anna Gilbert.

Metric repair on manifolds with holes

Abstract: For many machine learning tasks, the input data lie on a low-dimensional manifold embedded in a high- dimensional space and, because of this high-dimensional struc- ture, most algorithms inefficient. The typical solution is to reduce the dimension of the input data using a standard dimension reduction algorithms such as ISOMAP, LAPLACIAN EIGENMAPS or LLES. This approach, however, does not always work in practice as these algorithms require that we have somewhat ideal data. Unfortunately, most data sets either have missing entries or unacceptably noisy values. That is, real data are far from ideal and we cannot use these algorithms directly.

In this talk, we focus on the case when we have missing data. Some techniques, such as matrix completion, can be used to fill in missing data but these methods do not capture the non-linear structure of the manifold. Here, we present a new algorithm MR-MISSING that extends these previous algorithms and can be used to compute low dimensional representation on data sets with missing entries. We demonstrate the effectiveness of our algorithm by running three different experiments. We visually verify the effectiveness of our algorithm on synthetic manifolds, we numerically compare our projections against those computed by first filling in data using nlPCA and mDRUR on the MNIST data set, and we also show that we can do classification on MNIST with missing data. We also provide a theoretical guarantee for MR-MISSING under some simplifying assumptions.

10:05 - 12:10 A9 - Amphi 1: Time-frequency analysis. 10.05-10.30: The Strohmer and Beaver Conjecture for Gaussian Gabor Systems - A Deep Mathematical Problem (?)

Markus Faulhuber

Abstract: In this article we are going to discuss the conjecture of Strohmer and Beaver for Gaussian Gabor systems. It asks for an optimal sampling pattern in the time-frequency plane, where optimality is measured in terms of the condition number of the frame operator. From a heuristic point of view, it seems obvious that a hexagonal (sometimes called triangular) lattice should yield the solution. The conjecture is now open for 16 years and only recently partial progress has been made. One point this article aims to make, is to show up parallels to a long standing open problem from geometric function theory, Landau's problem (1929), suggesting that the conjecture of Strohmer and Beaver is a very deep mathematical problem.

10.30-10.55: Scaling limits in planar eigenvalue ensembles

Yacin Ameur

Abstract: In this article I present some of my recent research on scaling limits in two-dimensional eigenvalue ensembles.

10.55-11.20: A correspondence between zeros of time-frequency transforms and Gaussian analytic functions

Rémi Bardenet, Pierre Chainais, Julien Flamant & Adrien Hardy

Abstract: In this paper, we survey our joint work on the point processes formed by the zeros of time-frequency transforms of Gaussian white noises [1,2]. Unlike both references, we present the work from the bottom up, stating results in the order they came to us and commenting what we were trying to achieve. The route to our more general results was a sort of ping pong game between signal processing, harmonic analysis, and probability. We hope that narrating this game gives additional insight into the more technical aspects of the two references. We conclude with a number of open problems that we believe are relevant to the SampTA community.

11.20-11.45: The Diamond ensemble: a well distributed family of points on $\mathbb{S}^2$

Carlos Beltrán & Ujué Etayo

Abstract: We present our recent work on the Diamond ensemble, a constructive family of points on the unit sphere. Among the various characteristic of the Diamond ensemble we stand out that every set of points of the family is described by very simple formulas and that we can compute analytically also the expectation of the logarithmic energy of those sets of points. The value that we obtain for the logarithmic energy is by far, among the ones that have been proved for constructible sequences, the minimal to the date.

11.45-12.10: Filtering the Continuous Wavelet Transform Using Hyperbolic Triangulations

Günther Koliander, Luís Daniel Abreu, Antti Haimi, José Luis Romero

Abstract: We propose a methodology that detects signal components of a signal in white noise based on a hyperbolic triangulation of its wavelet transform (WT). The theoretical background is a connection between analyticity inducing wavelets and Gaussian analytic functions. This relation allows us to obtain some useful details on the random distribution of the zeros of the wavelet transformed signal. We apply our method to some acoustic signals and observe that many signal components are found but as predicted by the theory there is no guarantee to find all signal components.

10:05 - 12:10 A9 - Amphi 2: Compressed sensing.

10.05-10.30: Multiplication-free coordinate descent iteration for ℓ^1-regularized least squares

Nguyen T. Thao & Dominik Rzepka

Abstract: We propose a coordinate descent iteration for ℓ^1-regularized least-squares optimization that is free of multiplications. Although a suboptimal version of the ideal coordinate descent algorithm of Li and Osher, it contributes to major computational savings for only slight convergence degradations.

10.30-10.55: Random Gabor Multipliers and Compressive Sensing

Georg Tauböck, Shristi Rajbamshi, Peter Balazs & Luís Daniel Abreu

Abstract: We investigate the applicability of Gabor multipliers as compressive measurements. Specifically, we show that the canonical $M \times N$ matrix representation of a Gabor multiplier from $\mathbb{C}^N$ to $\mathbb{C}^M$ is full spark for almost all windows and multiplier symbol vectors with respect to the Lebesgue measure, provided that the length Q of the multiplier symbol vector satisfies $Q \geq N + M - 1$. Hence, if used as a measurement matrix in compressive sensing, $M \geq 2S$ guarantees perfect recovery of all S-sparse vectors by means of ℓ^0-minimization for almost all such Gabor multipliers. Furthermore, for ℓ^1-minimization, we demonstrate via simulations that Gabor multipliers with randomly chosen symbol vector have excellent capabilities in recovering sparse signals.

10.55-11.20: Parameter Instability Regimes in Sparse Proximal Denoising Programs

Aaron Berk, Yaniv Plan & Ozgur Yilmaz

Abstract: Compressed sensing theory explains why LASSO programs recover structured high-dimensional signals with minimax order-optimal error. Yet, the optimal choice of the program's governing parameter is often unknown in practice. It is still unclear how variation of the governing parameter impacts recovery error in compressed sensing, which is otherwise provably stable and robust. We establish a novel notion of instability in LASSO programs when the measurement matrix is identity. This is the proximal denoising setup. We prove asymptotic cusp-like behaviour of the risk as a function of the parameter choice, and illustrate the theory with numerical simulations. For example, a 0.1% underestimate of a LASSO parameter can increase the error significantly; and a 50% underestimate can cause the error to increase by a factor of 109. We hope that revealing parameter instability regimes of LASSO programs helps to inform a practitioner's choice.

11.20-11.45: Phase transition for eigenvalues and recovery of rank one matrices

Enrico Au-Yeung & Greg Zanotti

Abstract: In datasets where the number of parameters is fixed and the number of samples is large, principal component analysis (PCA) is a powerful dimension reduction tool. However, in many contemporary datasets, when the number of parameters is comparable to the sample size, PCA can be misleading. A closely related problem is the following: is it possible to recover a rank-one matrix in the presence of a large amount of noise? In both situations, there is a phase transition in the eigen-structure of the matrix.

11.45-12.10: Sparse synthesis regularization with deep neural networks

Daniel Obmann, Markus Haltmeier & Johannes Schwab

Abstract: We propose a sparse reconstruction framework for solving inverse problems. Opposed to existing sparse regularization techniques that are based on frame representations, we train an encoder-decoder network by including an ℓ^1-penalty. We demonstrate that the trained decoder network allows sparse signal reconstruction using thresholded encoded coefficients without losing much quality of the original image. Using the sparse synthesis prior, we minimize the ℓ^1-Tikhonov functional which is the sum of a data fitting term and the ℓ^1-norm of the synthesis coefficients.

10:05 - 12:10 A9 - Amphi 3: Deep learning.

10.05-10.30: Projection-Based 2.5D U-net Architecture for Fast Volumetric Segmentation

Christoph H. Angermann & Markus Haltmeier

Abstract: Convolutional neural networks are state-of-the-art for various segmentation tasks. While for 2D images these networks are also computationally efficient, 3D convolutions have huge storage requirements and require long training time. To overcome this issue, we introduce a network structure for volumetric data without 3D convolution layers. The main idea is to integrate projection layers to transform the volumetric data to a sequence of images, where each image contains information of the full data. We then apply 2D convolutions to the projection images followed by lifting to a volumetric data. The proposed network structure can be trained in much less time than any 3D-network and still shows accurate performance for a sparse binary segmentation task.

10.30-10.55: Unfavorable structural properties of the set of neural networks with fixed architecture

Philipp Petersen, Mones Raslan & Felix Voigtlaender

Abstract: In this note, we present a variety of results from the recent paper [1] in which the structural properties of the set of functions that can be implemented by neural networks with a fixed architecture have been studied. As it turns out, this set has many unfavorable properties: It is highly non-convex, except possibly for a few uncommon activation functions. Additionally, the set is not closed with respect to L^p-norms, $0 < p < infty$, for all frequently used activation functions, and also not closed with respect to the L^∞-norm for all practically-used activation functions except for the (parametric) ReLU. Finally, the function that maps a family of parameters to the function computed by the associated network is not inverse stable for every practically used activation function. Overall, our findings identify potential causes for issues in the optimization of neural networks such as no guaranteed or very slow convergence and the explosion of parameters.

10.55-11.20: Towards a Regularity Theory for ReLU Networks

Dennis Elbrächter, Julius Berner, Philipp Grohs & Arnulf Jentzen

Abstract: Although for neural networks with locally Lipschitz continuous activation functions the classical derivative exists almost everywhere, the standard chain rule is in general not applicable. We will consider a way of introducing a derivative for neural networks that admits a chain rule, which is both rigorous and easy to work with. In addition we will present a method of converting approximation results on bounded domains to global (pointwise) estimates. This can be used to extend known neural network approximation theory to include the study of regularity properties. Of particular interest is

the application to ReLU networks, where it contributes to a mathematical foundation for solving high-dimensional partial differential equations by deep learning methods without curse of dimensionality.

11.20-11.45: A rate-distortion framework for explaining deep neural network decisions

Stephan Wäldchen, Jan Macdonald, Sascha Hauch & Gitta Kutyniok

Abstract: We propose a rate-distortion framework for explaining deep neural network decisions. We formulate the task of determining the most relevant input signal components for a classifier prediction as an optimisation problem. For the special case of binary signals and Boolean classifier functions we show it to be NPˆPP-complete as well as NP-hard to approximate. Finally, we present a heuristic solution strategy based on assumed density filtering and tailored specifically to the case of deep ReLU neural network classifiers for which we present numerical experiments.

11.45-12.10: Deep-Sparse Array Cognitive Radar

Ahmet M. Elbir, Satish Mulleti, Regev Cohen, Rong Fu & Yonina C. Eldar

Abstract: In antenna array based radar applications, it is often desirable to choose an optimum subarray from a full array to achieve a balance between hardware cost and resolution. Moreover, in a cognitive radar system, the sparse subarrays are chosen based on the target scenario at that instant. Recently, a deep-learning based antenna selection technique was proposed for a single target scenario. In this paper, we extend this approach to multiple targets and assess the performance of state-of-the-art direction of arrival estimation techniques in conjunction with the proposed antenna selection method. To optimally choose the subarrays based on the target DOAs, we design a convolutional neural network which accepts the array covariance matrix as an input and selects the best sparse subarray that minimizes the mean square error. Once the optimum sparse subarray is obtained, the signals from the selected antennas are used to estimate the DOAs. We provide numerical simulations to validate the performance of the proposed cognitive array selection strategy. We show that the proposed approach outperforms random sparse antenna selection and it leads to a higher DOA estimation accuracy by 6 dB.

Tuesday Afternoon.

13:45 - 14:45 A22 - Wegener: Bubacarr Bah.

Combinatorial compressed sensing with expanders

Abstract: In spite of the square-root bottleneck for doing compressed sensing with binary matrices, the computational benefits of such sparse matrices triggered a lot interest in this area dubbed combinatorial compressed sensing. This talk will start from the introduction of the l1-norm restricted isometry property, which allows for optimal sampling rates but weaker instance optimality conditions to my most recent work on model-based combinatorial compressed sensing. There will be discussion on construction of expander graphs and hence expander matrices, both deterministic and random constructions. Recent improvements in random constructions and their implications for compressed sensing will also be discussed. Algorithms motivated by linear sketching for both standard compressed sensing and model-based compressed sensing with tree-sparse and loopless overlapping group-sparse model will be presented. The current state-of-the-art with more general models (overlapping group models for groups with bounded treewith and low frequency) and more efficient algorithms using head and tail approximations with model projections done via bender's decomposition will also be presented.

14:55 - 17:10 A9 - Amphi 1: Deep Learning. 14.55-15.20: Reconciling modern machine learning practice and the classical bias-variance trade-off

Mikhail Belkin, Daniel Hsu, Siyuan Ma & Soumik Mandal

Abstract: Breakthroughs in machine learning are rapidly changing society and science, yet fundamental understanding of learning currently lags behind. In classical machine learning, we find a model that balances under-fitting and over-fitting: complex enough to express underlying structure in data, simple enough to avoid fitting spurious patterns. In modern practice, we fit complex models like neural networks with zero training error but still obtain high accuracy on test data. Our objective is to resolve the apparent conflict between the classical understanding and modern practice. Our main result is a "double descent" risk curve that unifies the behavior in the classical and modern regimes. The mechanism underlying its emergence is posited. Our findings resolve the apparent conflict and inform how machine learning models should be designed and understood.

15.20-15.45: Overparameterized Nonlinear Optimization with Applications to Neural Nets

Samet Oymak

Abstract: Occam's razor is a fundamental problem-solving principal and states that one should seek the simplest possible explanation. Indeed, classical machine learning models such as (sparse) linear regression aims to find simple explanations to data by using with as few parameters as possible. On the other hand, modern techniques such as deep networks are often trained in the overparameterized regime where the model size exceeds the size of the training dataset. While this increases the risk of overfitting and the complexity of the explanation, deep networks are known to have good generalization properties. In this talk, we take a step towards resolving this paradox: We show that solution found by first order methods, such as gradient descent, has the property that it has near shortest distance to the initialization of the algorithm among all other solutions. We also advocate that shortest distance property can be a good proxy for the simplest explanation. We discuss the implications of these results on neural net training and also highlight some outstanding challenges.

15.45-16.10: General Bounds for 1-Layer *ReLU* approximation

Bolton R. Bailey & Matus Telgarsky

Abstract: The popularity of the *ReLU* has given rise to many neural networks which are piecewise affine. In this work, we show how a refined bound on the number of affine pieces in a single *ReLU* layer can be used to lower bound the approximation error of a *ReLU* network. We also demonstrate a method based on Rademacher complexity and random sampling to give an upper bound on the error of optimal approximations for these layers.

16.20-16.45: Generalization in deep nets: an empirical perspective

Tom Goldstein

Abstract: The power of neural networks lies in their ability to perform well on data that wasn't seen during training, a phenomena known as "generalization." Classical learning theory predicts that models generalize when they are under-parameterized, i.e., when the training set contains more samples than the number of model parameters. But strangely, neural nets generalize even when they have many more parameters than training data, and the underlying reasons for this good behavior remain elusive. Numerous rigorous attempts have been made to explain generalization, but available bounds are still quite loose, and analysis does not always lead to true understanding. The goal of this talk is to make generalization more intuitive. Using visualization methods, we discuss the mystery of generalization, the geometry of loss landscapes, and how the curse (or, rather, the blessing) of dimensionality causes optimizers to settle into minima that generalize well.

16.45-17.10: Neuron birth-death dynamics accelerates gradient descent and converges asymptotically

Joan Bruna

Abstract: Neural networks with a large number of parameters admit a mean-field description, which has recently served as a theoretical explanation for the favorable training properties of "overparameterized" models. In this regime, gradient descent obeys a deterministic partial differential equation (PDE) that converges to a globally optimal solution for networks with a single hidden layer under appropriate assumptions. In this work, we propose a non-local mass transport dynamics that leads to a modified PDE with the same minimizer. We implement this non-local dynamics as a stochastic neuronal birth/death process and we prove that it accelerates the rate of convergence in the mean-field limit. We subsequently realize this PDE with two classes of numerical schemes that converge to the mean-field equation, each of which can easily be implemented for neural networks with finite numbers of parameters. We illustrate our algorithms with two models to provide intuition for the mechanism through which convergence is accelerated.

Joint work with G. Rotskoff, S. Jelassi and E. Vanden-Eijnden

14:55 - 17:10 A9 - Amphi 2: Frame Theory.

14.55-15.20: Banach frames and atomic decompositions in the space of bounded operators on Hilbert spaces

Peter Balazs

Abstract: The concept of frames is used extensively for the representation of signal or functions. Recently this concept ia applied more and more for the representation of operators, both in theory as well as in the application for the numerical solutions of operator equations. In this paper we first give a survey about the matrix representation of operators using frames. Then we prove that the tensor product of frames forms a Banach frame and an atomic decomposition for the space of bounded operators of Hilbert spaces.

15.20-15.45: Frames by Iterations in Shift-invariant Spaces

Alejandra Aguilera, Carlos Cabrelli, Diana Carbajal & Victoria Paternostro

Abstract: In this note we solve the dynamical sampling problem for a class of shift-preserving (SP) operators, acting on a finitely generated shift-invariant space (FSIS). We find conditions on the operator and on a finite set of functions in the FSIS in order that the iterations of the operator on the functions produce a frame generator set. That is, the integer translations of the frame generator set is a frame of the FSIS. In order to obtain these results, we study the structure of SP operators and obtain a generalized finite dimensional spectral theorem.

15.45-16.10: Frame representations via suborbits of bounded operators

Ole Christensen & Marzieh Hasannasabjaldehbakhani

Abstract: The standard setup of dynamical sampling concerns frame properties of sequences of the form $\{T_n\varphi\}_{n=0}^{\infty}$, where T is a bounded operator on a Hilbert space H and $\varphi \in H$. In this paper we consider two generalizations of this basic idea. We first show that the class of frames that can be represented using iterations of a bounded operator increases drastically if we allow representations using just a subfamily $\{T^{\alpha(k)}\varphi\}_{k=1}^{\infty}$ of $\{T_n\varphi\}_{n=0}^{\infty}$; indeed, any linear independent frame has such a representation for a certain bounded operator T. Furthermore, we prove a number of results relating the properties of the frame and the distribution of the powers $\{\alpha(k)\}_{k=1}^{\infty}$ in $\mathbb{N}$. Finally, we show that also the condition of linear independency can be removed if we allow to consider approximate frame representations with an arbitrary small prescribed tolerance, in a sense to be made precise.

16.20-16.45: Sum-of-Squares Optimization and the Sparsity Structure of Equiangular Tight Frames

Dmitriy Kunisky & Afonso Bandeira

Abstract: Equiangular tight frames (ETFs) may be used to construct examples of feasible points for semidefinite programs arising in sum-of-squares (SOS) optimization. We show how generalizing the calculations in a recent work of the authors' that explored this connection also yields new bounds on the sparsity of (both real and complex) ETFs. One corollary shows that Steiner ETFs corresponding to finite projective planes are optimally sparse in the sense of achieving tightness in a matrix inequality controlling overlaps between sparsity patterns of distinct rows of the synthesis matrix. We also formulate several natural open problems concerning further generalizations of our technique.

16.45-17.10: Frame Potentials and Orthogonal Vectors

Josiah Park

Abstract: An extension is given of a recent result of Glazyrin, showing that an orthonormal basis $\{e_i\}_{i=1}^{d}$ joined with the vectors $\{e_i\}_{i=1}^{d}$, where $1 \leq m < d$ minimizes the p-frame potential for $p \in [1, 2\log\frac{2m+1}{2m}/\log\frac{m+1}{m}]$ over all collections of $N = d + m$ vectors $\{x_1, \ldots, x_n\}$ in $\mathbb{S}^{d-1}$.

17.10-17.35: Compactly Supported Tensor Product Complex Tight Framelets with Directionality

Xiaosheng Zhuang & Bin Han

Abstract: Construction of directional compactly supported tensor product complex tight framelets $cptTP - \mathbb{C}TF6$ is discussed. The construction algorithms employ optimization techniques and put extensive emphasis on frequency response and spatial localization of the underlying one-dimensional tight framelet filter banks. A concrete example of $cptTP - \mathbb{C}TF6$ is provided. Numerical experiments show that such constructed $cptTP - \mathbb{C}TF6$ have good performance for applications such as image denoising.

14:55 - 16:10 A9 - Amphi 3: Phase Retrieval. 14.55-15.20: Phase Estimation from Noisy Data with Gaps

Yitong Huang, Clark Bowman, Olivia Walch & Daniel Forger

Abstract: Determining the phase of a rhythm embedded in a time series is a key step in understanding many oscillatory systems. While existing approaches such as harmonic regression and cross-correlation are effective even when some data are missing, we show that they can produce biased estimates of phase when missing data are consecutive (i.e., there is a gap). We propose a simple modification of the least-squares approach, Gap Orthogonalized Accelerated Least Squares (GOALS), which addresses this issue with a negligible increase in computational expense. We test GOALS against other approaches on a synthetic dataset and on a real-world dataset of activity recorded by an Apple Watch, showing in both cases that GOALS is effective at recovering phase estimates from noisy data with gaps.

15.20-15.45: Phase retrieval from local correlation measurements with fixed shift length

Oleh Melnyk, Frank Filbir & Felix Krahmer

Abstract: Driven by ptychography, we consider an extension of the phase retrieval from local correlation measurements with shifts of length one to any fixed shift length. As a result, we provide an algorithm and recovery guarantees for extended model.

15.45-16.10: Ill-conditionedness of discrete Gabor phase retrieval and a possible remedy

Matthias Wellershoff & Rima Alaifari

Abstract: In light of recent work on continuous Gabor phase retrieval, we analyse discrete Gabor phase retrieval problems and note that under realistic decay assumptions on the window functions, the stability constants increase significantly in the space dimension. When using discretisations of the Gaussian as windows, we are in fact able to show that the stability constants grow at least exponentially as the dimension of the space increases. At the same time, we observe that the adversarial examples, which we construct to estimate the stability constants, all contain long modes of silence. This suggests that one should try to reconstruct signals up to so-called semi-global phase factors and not up to a global phase factor as is the canon in the literature. This observation is further corroborated by a stability result for discrete Gabor phase retrieval which we have proven recently.

16:20 - 17:10 A9 - Amphi 3: Quantization. 16.20-16.45: Higher order 1-bit Sigma-Delta modulation on a circle

Olga Graf, Felix Krahmer & Sara Krause-Solberg

Abstract: Manifold models in data analysis and signal processing have become more prominent in recent years. In this paper, we will look at one of the main tasks of modern signal processing, namely, at analog-to- digital (A/D) conversion in connection with a simple manifold model (circle). We will focus on Sigma-Delta modulation which is a popular method for A/D conversion of bandlimited signals that employs coarse quantization coupled with oversampling. Classical Sigma-Delta schemes would provide mismatches and large errors at the initialization point if the signal to be converted is defined on a circle. In this paper, our goal is to get around these problems for higher order Sigma-Delta schemes. Our results show how to design an update for the second and third order schemes based on the reconstruction error analysis such that for the updated scheme the reconstruction error is improved.

16.45-17.10: One-Bit Compressed Sensing Using Smooth Measure of ℓ^0 Norm

Sina Alemohammad & Arash Amini

Abstract: Quantization of signals and parameters happens in all digital data acquisition devices. It is commonly regarded as a non-ideality of the system, and shall be taken into account when designing or analyzing a system. The topic of one-bit compressed sensing studies the effect of quantization in the extreme case where the samples are quantized with only one bit, i.e., the sign bit. The recovery of a sparse signal based on one-bit measurements is widely accomplished via thresholding methods or variants of ℓ^1-minimization techniques. In this paper, we introduce a recovery method arising from smoothing directly the ℓ^0 pseudo-norm. While we numerically verify the superior performance of the

proposed method compared to the state-of-the-art techniques in our simulations, we briefly discuss the convergence analysis of this method.

18:00 - 20:00 Haut-Carré: Poster. Compressed Diffusion

Scott Gigante, Jay S. Stanley III, Ngan Vu, David Van Dijk, Kevin Moon, Guy Wolf & Smita Krishnaswamy

Abstract: Diffusion maps are a commonly used kernel-based method for manifold learning, which can reveal intrinsic structures in data and embed them in low dimensions. However, as with most kernel methods, its implementation requires a heavy computational load, reaching up to cubic complexity in the number of data points. This limits its usability in modern data analysis. Here, we present a new approach to computing the diffusion geometry, and related embeddings, from a compressed diffusion process between data regions rather than data points. Our construction is based on an adaptation of the previously proposed measure-based (MGC) kernel that robustly captures the local geometry around data points. We use this MGC kernel to efficiently compress diffusion relations from pointwise to data region resolution. Finally, a spectral embedding of the data regions provides coordinates that are used to interpolate and approximate the pointwise diffusion map embedding of data. We analyze theoretical connections between our construction and the original diffusion geometry of diffusion maps, and demonstrate the utility of our method in analyzing big datasets, where it outperforms competing approaches.

A Joint Deep Learning Approach for Automated Liver and Tumor Segmentation

Nadja Gruber & Markus Haltmeier

Abstract: Hepatocellular carcinoma (HCC) is the most common type of primary liver cancer in adults, and the most common cause of death of people suffering from cirrhosis. The segmentation of liver lesions in CT images allows assessment of tumor load, treatment planning, prognosis and monitoring of treatment response. Manual segmentation is a very time-consuming task and in many cases, prone to inaccuracies and automatic tools for tumor detection and segmentation are desirable. In this paper, we use a network architecture that consists of two consecutive fully convolutional neural networks. The first network segments the liver whereas the second network segments the actual tumor inside the liver. Our network is trained on a subset of the LiTS (Liver Tumor Segmentation) Challenge and evaluated on data provided from the radiological center in Innsbruck.

Adapted Decimation on Finite Frames for Arbitrary Orders of Sigma-Delta Quantization

Kung-Ching Lin

Abstract: In Analog-to-digital (A/D) conversion, signal decimation has been proven to greatly improve the efficiency of data storage while maintaining high accuracy. When one couples signal decimation with the $\Sigma\Delta$ quantization scheme, the reconstruction error decays exponentially with respect to the bit-rate. We build on our previous result, which extends signal decimation to finite frames, albeit only up to the second order. In this study, we introduce a new scheme called adapted decimation, which yields polynomial reconstruction error decay rate of arbitrary order with respect to the oversampling rate, and exponential with respect to the bit-rate.

Adaptive Rate EEG Signal Processing for Epileptic Seizure Detection

Saeed Qaisar & Abdulhamit Subasi

Abstract: A big number of people all over the world is affected by epilepsy. Electroencephalography (EEG) is a crucial component in the evaluation of epilepsy. Onset seizure detection is essential to prevent the seizure activity and improve patients' life quality. Presurgical treatment, precise assessment, seizure prevention, and emergency alerts all depend on the quick detection of seizure onset. Moreover, manual examination of EEG signals is boring and time-consuming task. Numerous automated epileptic seizure detection schemes have been developed to help neurologists. This paper focus on the realization of an efficient adaptive rate solution for the epileptic seizure detection. The signal is respectively digitized and segmented with an event-driven ADC (EDADC) and an activity selection algorithm (ASA). The segments are uniformly resampled and conditioned. In next step, the autoregressive (AR) Burg modelling is employed to extract the features. Afterwards, the extracted features are utilized for classification. It is demonstrated that the suggested system-processing load is adjusted as a function of the incoming signal disparities. It allows the suggested solution to attain a remarkable reduction in the processing activity and consumption of power compared to the counter classical ones. The overall system classification precision is also compared with the counter classical one. It confirms that the prospect of using the suggested system for an effective automatic epileptic seizure detection.

Reconstructing high-dimensional Hilbert-valued functions via compressed sensing

Nicholas C. Dexter, Clayton Webster & Hoang A. Tran

Abstract: We present and analyze a novel sparse polynomial technique for approximating high-dimensional Hilbert- valued functions, with application to parameterized partial differential equations (PDEs) with deterministic and stochastic inputs. Our theoretical framework treats the function approximation as a jointly sparse recovery problem, where the set of jointly sparse vectors is possibly infinite. To achieve the simultaneous reconstruction of Hilbert-valued functions in both parametric domain and Hilbert space, we propose a novel mixed-norm based ℓ^1-regularization method that exploits both energy and sparsity. Our approach requires extensions of concepts such as the restricted isometry and null space properties, allowing us to prove recovery guarantees for sparse Hilbert-valued function reconstruction. We complement the enclosed theory with modifications to standard sparse recovery algorithms, meanwhile establishing their strong convergence in the considered infinite-dimensional setting. Finally, we demonstrate the minimal sample complexity requirements of our approach, relative to other popular methods, with numerical experiments approximating the solutions of a high-dimensional parameterized elliptic PDEs.

Construction of Non-Uniform Parseval Wavelet Frames for $L^2(\mathbb{R})$ via UEP

Hari Hari Krishan Malhotra & Lalit K. Vashisht

Abstract: We study the construction of non-uniform Parseval wavelet frames for the Lebesgue space $L^2(\mathbb{R})$, where the related translation set is not necessary a group. The unitary extension principle (UEP) and generalized (or oblique) extension principle (OEP) for the construction of multi-generated non-uniform Parseval wavelet frames for $L^2(\mathbb{R})$ are discussed. Some examples are also given to illustrate our results.

A directional periodic uncertainty principle

Elena Lebedeva, Aleksander Krivoshein & Jürgen Prestin

Abstract: A notion of a directional uncertainty product for multivariate periodic functions is introduced. It is a characteristic of a localization for a signal along a fixed direction.

Compressive Sampling and Least Squares based Reconstruction of Correlated Signals

Ali Ahmed & Fahad Shamshad

Abstract: This paper presents a novel sampling scheme for the acquisition of an ensemble of *correlated* (lying in an a priori unknown subspace) signals at a sub-Nyquist rate. We propose an implementable sampling architecture that acquires structured samples of the signals. We then show that a much fewer of these samples compared to what is dictated by the Shannon-Nyquist sampling theorem suffice for exact signal reconstruction. Quantitatively, we show that an ensemble of M correlated signals each of which is bandlimited to $W/2$ and can be expressed as the linear combination of R underlying signals can be acquired at roughly RW (to with log factors) samples per second. This is a considerable gain in sampling rate compared to MW samples required by Shannon-Nyquist sampling in the case when $M \gg R$. We propose a simple least squares program for the reconstruction of the correlated signal ensemble. This result is in stark contrast with the previous work, where a prohibitively computationally expensive semidefinite program is required for signal reconstruction.

Deterministic matrices with a restricted isometry property for partially structured sparse signals

Alihan Kaplan, Volker Pohl & Holger Boche

Abstract: Although compressive sampling has become important in diverse application areas one of its main challenges, i.e. the construction of deterministic sensing matrices with restricted isometry property (RIP) in the optimal sparsity regime, still remains an open problem despite being of crucial importance for practical system designs. The only known work constructing deterministic RIP matrices beyond the square root bottleneck is due to Bourgain et al. The aim of this paper is to construct sensing matrices consisting of two orthogonal bases and to analyse their RIP properties based on the flat-RIP. Using a known estimation on exponential sums due to Chang, we deduce an RIP result for signals which are restricted to a certain sparse structure. Without any assumption on the sparsity structure, we end up facing a known open problem from number theory regarding exponential sums.

Frame Bounds for Gabor Frames in Finite Dimensions

Palina Salanevich

Abstract: One of the key advantages of a frame compared to a basis is its redundancy. Provided we have a control on the frame bounds, this redundancy allows, among other things, to achieve robust reconstruction of a signal from its frame coefficients that are corrupted by noise, rounding error, or erasures. In this paper, we discuss frame bounds for Gabor frames with a generic frame set and a random window. We show that, with high probability, such frames have frame bounds similar to the frame bounds of randomly generated frames with independent frame vectors.

Lagrange interpolation of bandlimited functions on slowly increasing sequences

Louie John Vallejo & Noli Reyes

Abstract: Let $\Lambda = \{z_{n,k} : 1 \leq k \leq n, n \in \mathbb{N}\}$ be a triangular array of distinct complex numbers and let f be an entire function. Suppose $L_{n-1}f$ is the unique polynomial of degree at most $n-1$ which interpolates f at $z_{n,k}$ for $k \in \{1, \ldots, n\}$, i.e., $L_{n-1}f(z_{n,k}) = f(z_{n,k})$. In this note, we show that $L_n f$ converges to f uniformly on compact subsets of the complex plane provided Λ is bounded. We next consider the case when $z_{n,k} = z_k$ where $\{|z_k|\}_{k\in\mathbb{N}}$ is a slowly increasing unbounded sequence in the sense that for some $\alpha \in (0,1)$, $(k-1)\alpha \leq |z_k| \leq k\alpha$ for each $k \in \mathbb{N}$. If f is bandlimited, we prove as well that $L_n f$ converges uniformly (and rapidly) to f on compact subsets of the complex plane. The rate of convergence that we obtain is optimal to some extent.

Network Tomography in Hyperbolic Space

Stephen D. Casey

Abstract: The paper addresses the problems of network analysis and network security, outlining a computationally feasible method of monitoring networks, and detecting (hyper)-active increase in subnetwork activity, such as one would see in viral or network attack activity. Additionally, it outlines a systematic method of detecting the source of activity, and if needed, isolate and/or shut-down subcomponents of the network.

Near optimal polynomial regression on norming meshes

Marco Vianello, Federico Piazzon & Len Bos

Abstract: We connect the approximation theoretic notions of polynomial norming mesh and Tchakaloff-like quadrature to the statistical theory of optimal designs, obtaining near optimal polynomial regression at a near optimal number of sampling locations on domains with different shapes.

Nonuniform Sampling of Echoes of Light

Miguel Heredia Conde, Ayush Bhandari & Otmar Loffeld

Abstract: Recent work on time-resolved imaging (TRI) has shown that real-world scenes can often be explained by means of sparse time-domain responses. Direct sampling of such scene responses in the time-domain requires exorbitant sampling rates posing a practical bottleneck. An alternative approach uses sinusoidal illumination whereby the phase difference encodes time delays. When working with multiple frequencies this allows for directly sampling the Fourier spectrum of sparse scene responses and this is made possible using a Time-of-Flight (ToF) camera. Due to hardware restrictions, creating an equidistant set of frequencies is challenging. In this paper we adopt a nonuniform sampling architecture and propose an extension of the real-valued IAA (RIAA) algorithm which sequentially

estimates the sparse components. Experimental validation with both synthetic and real data acquired with a ToF sensor confirms the feasibility of the proposed approach. This leverages the requirements on the hardware and paves the way for accurate scene response sensing with low-cost ToF sensors.

NP-hardness of L^0 minimization problems: revision and extension to the non-negative setting

Thi-Thanh Nguyen, Charles Soussen, Jérôme Idier & El-Hadi Djermoune

Abstract: Sparse approximation arises in many applications and often leads to a constrained or penalized L^0 minimization problem which was proved to be NP-hard. In this work we revise the existing analyses of NP-hardness of penalized L^0 minimization problem and introduce a new proof by an adaptation of Natarajan's construction (1995). Moreover, for the first time, we prove that L0 minimization problems with non-negativity constraints are also NP-hard.

On Column-Row Matrix Approximations

Keaton Hamm & Longxiu Huang

Abstract: This article discusses column-row factorizations of low-rank matrices, and extensions of these to approximations of full rank matrices. We consider the stability of column and row sampling methods and give perturbation estimates for the factorizations. We also provide some numerical experiments to guide how such approximations might be done in practice.

On Inferences from Completed Data

Jamie Haddock

Abstract: Matrix completion has become an extremely important technique as data scientists are routinely faced with large, incomplete datasets on which they wish to perform statistical inferences. We investigate how error introduced via matrix completion affects statistical inference. Furthermore, we prove recovery error bounds which depend upon the matrix recovery error for several common statistical inferences. We consider matrix recovery via nuclear norm minimization and a variant, ℓ^1-regularized nuclear norm minimization for data with a structured sampling pattern. Finally, we run a series of numerical experiments on synthetic data and real patient surveys from MyLymeData, which illustrate the relationship between inference recovery error and matrix recovery error. These results indicate that exact matrix recovery is often not necessary to achieve small inference recovery error.

On Kantorovich-type sampling operators

Gert Tamberg & Olga Graf

Abstract: The generalized sampling operators depend on the exact values of functions, whilst in many applications only the local averages are known. For this reason we consider the Kantorovich-type sampling operators. In this paper we use the results we have for the generalized sampling operators to prove the analogous results for the Kantorovich-type sampling operators. In particular, some results on the order of approximation via the modulus of smoothness are obtained.

Random Diffusion Representations

Moshe Salhov & Amir Averbuch

Abstract: The diffusion maps is a kernel based method for manifold learning and data analysis that models a Markovian process over data. Analysis of this process provides meaningful information about the inner geometric structures in the data. In this paper, we present a representation framework for analyzing datasets. This framework is based on a random approximation of the diffusion maps kernel. The resulted representation approximate the pair-wise diffusion distance, does not depend on the data size and it is invariant to scale.

Brain Activity Estimation using EEG-only Recordings Calibrated with joint EEG-fMRI Recordings using Compressive Sensing

Ali Ataei, Arash Amini & Ali GhaziZadeh

Abstract: Electroencephalogram (EEG) is a noninvasive, low-cost brain recording tool with high temporal but poor spatial resolution. In contrast, functional magnetic resonance imaging (fMRI) is a rather expensive brain recording tool with high spatial and poor temporal resolution. In this study, we aim at recovering the brain activity (source localization and activity-intensity) with high spatial resolution using only EEG recordings. Each EEG electrode records a linear combination of the activities of various parts of the brain. As a result, a multi-electrode EEG recording represents the brain activities via a linear mixing matrix. Due to distance attenuation, this matrix is almost sparse. Using simultaneous recordings of fMRI and EEG, we estimate the mixing matrix (calibration). Since Blood Oxygen Level Dependent (BOLD) signal of fMRI is a measure of energy used by active brain region, it has a quadratic relation with the electric potential waveform emitted from each fMRI *volume pixel* (voxel). Assuming uncorrelated time series from different regions, we reformulate the (underdetermined) forward problem as a linear problem and solve it using the Orthogonal Matching Pursuit (OMP) method. Besides the mixing matrix, the brain activities are often sparse spatially. Thus, we employ the estimated mixing matrix to extract the activity intensity of various brain regions from EEG recordings using iterative shrinkage thresholding algorithm (ISTA). We verify the proposed method on synthetic data. In particular, we divide the gray matter of the brain into 300 regions and assume a 30%-sparse measurement matrix, as well as 5% of regions to be active simultaneously. Simulations results show 88% accuracy in localizing the sources and and 66% accuracy in activity intensity estimation.

Recovery of a class of Binary Images from Fourier Samples

Saeed Razavi-Kia, Hojatollah Zamani & Arash Amini

Abstract: In this paper, we study the recovery of a certain type of shape images modeled as binary-valued images from few Fourier samples. In particular, the boundary of the shapes is assumed to be the zero level-set of a trigonometric curve. This problem was previously considered in [1], and it was shown that such images can be studied within the framework of signals with finite rate of innovation. In particular, an annihilation filter is introduced to recover the trigonometric boundary curve. It is proved in [1] that 3Λ Fourier samples are sufficient to exactly recover the edges of a binary shape, where Λ is the bandwith of the trigonometric boundary curve. In this paper, we introduce a class of shapes (that include convex shapes as special cases) for which $2\Lambda+1$ Fourier samples are sufficient for exact recovery using the same annihilation filter. Simulation results support our theoretical results.

Sampling and Recovery of Binary Shapes via Low-Rank structures

Saeed Razavi-Kia, Hojatollah Zamani & Arash Amini

Abstract: The binary-valued images usually represent shapes. Therefore, the recovery of binary images from samples is often linked with recovery of shapes, where certain parametric structures are assumed on the shape. In this paper, we study the recovery of shape images with the perspective of low-rank matrix recovery. The matrix of such images is not automatically low-rank. Therefore, we consider the Hankel transformation of binary images in order to apply tools in low-rank matrix recovery. We introduce an ADMM technique for the reconstruction which is numerically confirmed to yield suitable results. We also analyze the sampling requirement of this process based on the theory of random matrices.

Unitarization and Inversion Formula for the Radon Transform for Hyperbolic Motions

Francesca Bartolucci & Matteo Monti

Abstract: Following a wider version of Helgason's approach based on intertwining properties for irreducible quasi-regular representations, we construct the Radon transform associated to the group of hyperbolic motions of the plane and we obtain a unitarization result and an inversion formula for this Radon transform.

Wednesday Morning.

8:30 - 9:30 A22 - Wegener: Ursula Molter.

Approximation by crystal invariant subspaces

Abstract: In this talk we will look at approximation properties of spaces invariant under the action of a crystal group. We show how to characterize these spaces by a property of the range function. Using this fact and the results for shift invariant spaces, we show how to solve the following problem:

Let $\mathcal{F} := \{f_1, \ldots, f_m\}$ (the data) be given vectors of a Hilbert space $\mathcal{H}$. Which is the crystal invariant subspace $S \subset \mathcal{H}$ of k generators that minimizes the error to the data, in the sense that

$$\sum_{i=1}^{m} \|f_i - P_S(f_i)\|^2$$

is minimal, where P_S is the orthogonal projection onto S.

This provides a rotational invariant model for images.

10:05 - 12:10 A9 Amphi 1: Phase Retrieval. 10.05-10.30: 3D Phaseless Imaging at Nano-scale: Challenges and Possible Solutions

Mahdi Soltanolkotabi

Abstract: In a variety of scientific applications we are interested in imaging 3D objects at very fine resolutions. However, we typically can not measure the object or its footprint directly. Rather restricted by fundamental laws governing the propagation of light we have access to 2D magnitude-only measurements of the 3D dimensional object through highly nonlinear projection mappings. Therefore, reconstructing the object requires inverting highly nonlinear and seemingly non-invertible mappings. In this paper we discuss some of the challenges that arises in such three dimensional phaseless imaging problems and offer possible solutions for 3D reconstruction. In particular we demonstrate how variants of the recently proposed Accelerated Wirtinger Flow (AWF) algorithm can enable precise 3D reconstruction at unprecedented resolutions.

10.30-10.55: Optimally Sample-Efficient Phase Retrieval with Deep Generative Models

Oscar Leong, Paul Hand & Vladislav Voroninski

Abstract: We consider the phase retrieval problem, which asks to recover a structured £n£-dimensional signal from m quadratic measurements. In many imaging contexts, it is beneficial to enforce a sparsity prior on the signal to reduce the number of measurements necessary for recovery. However, the best known methodologies for sparse phase retrieval have a sub-optimal quadratic dependency on the sparsity level of the signal at hand. In this work, we instead model signals as living in the range of a deep generative neural network $G : \mathbb{R}^k \to \mathbb{R}^n$. We show that under the model of a d-layer feed forward neural network with Gaussian weights, $m = O(kd^2 \log n)$ generic measurements suffice for the ℓ^2 empirical risk minimization problem to have favorable geometry. In particular, we exhibit a descent direction for all points outside of two arbitrarily small neighborhoods of the true k-dimensional latent code and a negative reflection of it. Our proof is based on showing the sufficiency of two deterministic conditions on the generator and measurement matrices, which are satisfied with high probability under random Gaussian ensembles. We corroborate these results with numerical experiments showing that enforcing a generative prior via empirical risk minimization outperforms sparse phase retrieval methods.

10.55-11.20: The Cramer-Rao Lower Bound in the Phase Retrieval Problem

Radu Balan & David Bekkerman

Abstract: This paper presents an analysis of Cramer-Rao lower bounds (CRLB) in the phase retrieval problem. Previous papers derived Fisher Information Matrices for the phaseless reconstruction setup. Two estimation setups are presented. In the first setup the global phase of the unknown signal is determined by a correlation condition with a fixed reference signal. In the second setup an oracle provides the optimal global phase. The CRLB is derived for each of the two approaches. Surprisingly (or maybe not) they are different.

11.20-11.45: Stability of the Phase Retrieval Problem

Palina Salanevich

Abstract: Phase retrieval is a non-convex inverse problem of signal reconstruction from intensity measurements with respect to a measurement frame. One of the main problems in phase retrieval is to determine for which frames the associated phaseless measurement map is injective and stable. In this paper we address the question of stability of phase retrieval for two classes of random measurement maps, namely, frames with independent frame vectors satisfying bounded fourth moment assumption and frames with no independence assumptions. We propose a new method based on the frame order statistics, which can be used to establish stability of the measurement maps for other classes of frames.

11.45-12.10: PhasePack: A Phase Retrieval Library

Tom Goldstein, Christoph Studer & Rohan Chandra

Abstract: Phase retrieval deals with the estimation of complex-valued signals solely from the magnitudes of linear measurements. While there has been a recent explosion in the development of phase retrieval algorithms, the lack of a common interface has made it difficult to compare new methods against the state-of-the-art. We introduce PhasePack with the purpose of creating a common software interface for a wide range of phase retrieval algorithms and to provide a common testbed using both synthetic data and empirical imaging datasets. Using PhasePack, we examine a number of issues. Can the performance of convex relaxation methods compete with non-convex approaches? How much does initialization affect results, and which initialization methods work best? Can methods that are designed and analyzed for Gaussian random measurements be effectively applied to empirical data?

10:05 - 12:10 A9 Amphi 2: Non-Euclidean signal processing.

10.05-10.30: Generalized Sampling on Graphs With A Subspace Prior

Yuichi Tanaka & Yonina C. Eldar

Abstract: We consider a framework for generalized sampling of graph signals that extends sampling results in shift-invariant (SI) spaces to the graph setting. We assume that the input signal lies in a periodic graph spectrum subspace, which generalizes the standard SI assumption to graph signals. Sampling is performed in the graph frequency domain by an arbitrary graph filter. We show that under a mild condition on the sampling filter, perfect recovery is possible using a correction filter that can be represented as a spectral graph filter whose response depends on the prior subspace spectrum and on the sampling filter. This filter parallels the correction filter in SI sampling in standard signal processing. Since the input space and the sampling filter are almost arbitrary, our framework allows perfect recovery of many classes of input signals from a variety of different sampling patterns using a simple correction filter. For example, our method enables perfect recovery of non-bandlimited graph signals from their bandlimited measurements.

10.30-10.55: Numerical computation of eigenspaces of spatio-spectral limiting on hypercubes

Joseph Lakey & Jeffrey Hogan

Abstract: Hypercubes are Cayley graphs of the N-fold product of the integers mod two. Spatio–spectral limiting on hypercubes refers to truncation to the path neighborhood of a vertex, followed by projection onto small eigenmodes of the graph Laplacian. We present a method to compute eigenspaces of spatio–spectral limiting on hypercubes leveraging recent work of the authors that provides a geometric identification of the eigenspaces.

10.55-11.20: On the Transferability of Spectral Graph Filters

Ron Levie, Elvin Isufi & Gitta Kutyniok

Abstract: This paper focuses on spectral filters on graphs, namely filters defined as elementwise multiplication in the frequency domain of a graph. In many graph signal processing settings, it is important to transfer a filter from one graph to another. One example is in graph convolutional neural networks (ConvNets), where the dataset consists of signals defined on many different graphs, and the learned filters should generalize to signals on new graphs, not present in the training set. A necessary condition for transferability (the ability to transfer filters) is stability. Namely, given a graph filter, if we add a small perturbation to the graph, then the filter on the perturbed graph is a small perturbation of the original filter. It is a common misconception that spectral filters are not stable, and this paper aims at debunking this mistake. We introduce a space of filters, called the Cayley smoothness space, that contains the filters of state-of-the-art spectral filtering methods, and whose filters can approximate any generic spectral filter. For filters in this space, the perturbation in the filter is bounded by a constant times the perturbation in the graph, and filters in the Cayley smoothness space are thus termed linearly stable. By combining stability with the known property of equivariance, we prove that graph spectral filters are transferable.

11.20-11.45: Sampling on Hyperbolic Surfaces

Stephen D. Casey

Abstract: We discuss harmonic analysis in the setting of hyperbolic space, and then focus on sampling theory on hyperbolic surfaces. We connect sampling theory with the geometry of the signal and its domain. It is relatively easy to demonstrate this connection in Euclidean spaces, but one quickly gets into open problems when the underlying space is not Euclidean. We discuss how to extend this connection to hyperbolic geometry and general surfaces, outlining an Erlangen-type program for sampling theory.

11.45-12.10: Random Sampling for Bandlimited Signals on Product Graphs

Rohan Varma & Jelena Kovačević

Abstract: In this work, we construct a structured framework for the efficient random sampling and recovery of bandlimited graph signals that lie on product graphs. Product graphs are a model to construct large complex graphs from smaller simpler building blocks we call graph atoms, and are a convenient tool to model rich classes of multi-modal graph-structured data. Our randomized sampling framework prescribes an optimal sampling distribution over the nodes of the product graph constructed by only processing these smaller graph atoms. As a result, the framework achieves significant savings in computational complexity with respect to previous works that do not exploit the inherent structure of product graphs.

Thursday Morning.

08:30 - 9:30 A22 - Wegener: Urbashi Mitra.

Bagging the Peaks: Matrix and Tensor Factorization with Unimodal Constraints

Abstract: We consider matrix and tensor factorization problems where there are both unimodal and rank constraints. Such methods find application in a variety of problems such as target localization, environmental monitoring, epidemic detection, and medical diagnosis. We presume that we have incomplete (sparse) and noisy samples of a particular field or image and that our objects of interest have spatial extent and can be modeled as low rank and unimodal: there is a single strong signal peak and this signal decays as one moves away from the strong signal peak. By exploiting modern signal processing techniques such as matrix completion and active search methods, we develop a high performance, moderate complexity algorithm for peak detection. This method is extended to the case of multiple targets via novel matrix factorization and isotonic projection methods. We further extend the approach to handle multimodal sensor data by exploiting tensor completion methods. Finally, we show how we can exploit our methods to solve a data clustering problem which is motivated by the application of radio map building. Radio signals in urban environments can be described by multiple propagation models. We can transform and compress location-labeled wireless channel measurements into a low-dimensional feature matrix. By analyzing the local peaks of the feature matrix, we can identify the regional propagation laws, which enable the clustering of the data. Theoretical performance bounds derived and properties of key matrices are proven. The methods are compared against the state of the art on both synthetic and real data sets and shown to offer superior performance with moderate complexity.

10.05-12.10 A9 Amphi 1: Missing Data Imputation. **10.05-10.30: Comparison of Imputation Methods for Race and Ethnic Information in Administrative Health Data**

Ofer Harel, Yishu Xue & Robert Aseltine

Abstract: In the United States of America where there is no national health care, All-Payer Claims Databases provide great resources to investigate and address disparities in access to, utilization, and outcomes of care. Race/ethnicity being missing, however, is a bottleneck on its usage. In most health claim databases Race/ethnicity only observed to $3-5\%$ of the observations, causing a great missing data problem. We try to recover race/ethnicity information for incomplete observations based on studies of the (3%) complete observations. To emulate the data structure, an analysis of birth records from Connecticut is done where the race/ethnicity information is complete, in order to assess competing models performances. While the CT-based full model based on logistic model proposed achieves over 80% prediction accuracy, we are interested in comparing this model performance to more complex machine learning methods and evaluate prediction. An empirical study is presented.

10.30-10.55: Adaptive sequential regression imputation methods using machine learning techniques

Trivellore E. Raghunathan

Abstract: Multiple imputation is used for a variety of problems that can be formulated as missing data problem. Under this approach, the set of missing values are replaced by a several plausible sets of values to created several completed data sets. Each completed data set is analyzed separately and the results are combined. The crux of the problem, of course, is the creation of plausible sets of values. One potential approach is the Sequential Regression Imputation Method (SRIM) (also called Chained Equations) where the predictive distributions of the missing set of values are constructed through a sequence conditional regression models for each variable with missing values and all other variables as predictors. This paper proposes to use a collection of machine learning tools for an adaptive selection of regression models to ensure that the underlying assumptions are satisfied and, finely tuned, if not. A numerical illustration and simulation study evaluate the properties the proposed approach.

10.55-11.20: Tractable Learning of Sparsely Used Dictionaries from Incomplete Sample

Thanh Nguyen, Akshay Soni & Chinmay Hegde

Abstract: In dictionary learning, we seek a collection of atoms that sparsely represent a given set of training samples. While this problem is well-studied, relatively less is known about the more challenging case where the samples are incomplete, i.e., we only observe a fraction of their coordinates. In this paper, we develop and analyze an algorithm to solve this problem, provided that the dictionary satisfies additional low-dimensional structure.

11.20-11.45: Aggregation for Sensitive Data

Avradeep Bhowmik, Joydeep Ghosh & Oluwasanmi Koyejo

Abstract: In many modern applications, considerations like privacy, security and legal doctrines like the GDPR put limitations on data storage and sharing with third parties. Specifically, access to individual-level data points is restricted and machine learning models need to be trained with aggregated versions of the datasets. Learning with aggregated data is a new and relatively unexplored form of semi-supervision. We tackle this problem by designing aggregation paradigms that conform to certain kinds of privacy or non-identifiability requirements. We further develop novel learning algorithms that can nevertheless be used to learn from only these aggregates. We motivate our framework for the case of Gaussian regression, and subsequently extend our techniques to subsume arbitrary binary classifiers and generalised linear models. We provide theoretical results and empirical evaluation of our methods on real data from healthcare and telecom.

10.05-12.10 A9 Amphi 2: Fourier Analysis and Sampling.

10.05-10.30: Sampling over spiraling curves

Philippe Jaming, Felipe Negreira & José Luis Romero

Abstract: We present our recent work on sampling along spiral-like curves, and discuss the main techniques. As a first result we give a sharp density condition for sampling on spirals in terms of the separation between consecutive branches. We then further show that, below this rate, the numerical stability related to the reconstruction of compressible signals when sampled along spirals is significantly limited by the amount of undersampling.

10.30-10.55: Time encoding and perfect recovery of non-bandlimited signals with an integrate-and-fire system

Roxana Alexandru & Pier Luigi Dragotti

Abstract: Time encoding represents an alternative method of sampling, based on mapping the amplitude information of a signal into a time sequence. In this paper, we investigate the problem of time encoding based on an integrate-and-fire model, consisting of a feedback loop with an integrator and a threshold comparator. We focus on particular classes of non-bandlimited signals such as streams and bursts of Diracs, and prove we can recover these perfectly from their time information.

10.55-11.20: Optimal Spline Generators for Derivative Sampling

Shayan Aziznejad, Alireza Naderi & Michael Unser

Abstract: The goal of derivative sampling is to reconstruct a signal from the samples of the function and of its first-order derivative. In this paper, we consider this problem over a shift-invariant reconstruction subspace generated by two compact-support functions. We assume that the reconstruction subspace reproduces polynomials up to a certain degree. We then derive a lower bound on the sum of supports of its generators. Finally, we illustrate the tightness of our bound with some examples

11.20-11.45: On cosine operator function framework of windowed Shannon sampling operators

Andi Kivinukk, Olga Graf & Anna Saksa

Abstract: The aim of this paper is to consider the cosine-type Shannon sampling operators in the unified cosine operator function framework. In particular, we present the numerical estimates for the operator norms as well as for the order of approximation.

11.45-12.10: On Identifiability in Unlimited Sampling

Ayush Bhandari & Felix Krahmer

Abstract: In recent work, the authors introduced the Unlimited Sampling framework which establishes that a bandlimited function can be perfectly recovered from a constant-factor oversampling of its modulo samples, hence complementing recent developments in sensor design. This new sensing framework allows to overcome the clipping or saturation problem that is a fundamental limitation common to all formats of conventional digital sensing that rely on Shannon's sampling theorem. In contrast to critical sampling rate of one sample per second, the sampling density criterion prescribed by the Unlimited Sampling Theorem requires a factor of 2 pi e oversampling. In this paper, we prove identifiability conditions linked with the unlimited sensing setup. Our main result establishes that any sampling rate that is faster than critical sampling allows for one-to-one mapping between a finite energy bandlimited function and its modulo samples. This result is corroborated by experiments and opens further interesting questions around the topic as it relaxes the previously held oversampling criterion.

Thursday Afternoon.

13:45 - 14:45 A22 - Wegener: Marcin Bownik.

Lyapunov's theorem and sampling of continuous frames

Abstract: In this talk we describe several recent developments stimulated by the solution of the Kadison-Singer Problem by Marcus, Spielman, and Srivastava. This includes an extension of Lyapunov's theorem for discrete frames due to Akemann and Weaver and a similar extension for continuous frames by the speaker. We also discuss the discretization problem posed by Ali, Antoine, and Gazeau, which asks whether a continuous frame can be sampled to obtain a discrete frame. This problem was recently solved by Freeman and Speegle using the solution of the Kadison-Singer problem. Generalizations of these results for trace class operator valued measures are also discussed.

14.50-17.45 A9 Amphi 1: Graph Signal Processing. 14.50-15.15: Sampling and reconstruction of graph signals: An overview of recent graph signal processing results

Antonio G. Marques

Abstract: Networks are structures that encode relationships between pairs of elements of a set. The simplicity of this definition drives the application of graphs and networks to a wide variety of disciplines. While often networks have intrinsic value and are themselves the object of study, in other occasions the object of interest is a signal defined on top of the graph, i.e., data associated with the nodes of the network. This is the matter addressed in the field of graph signal processing (GSP), where the notions of, e.g., frequency, filtering, or stationarity have been extended to signals supported on graphs. The goal of this talk is to review recent results on reconstruction of graph signals from observations taken at a subset of nodes. Leveraging the notions such as the Graph Fourier Transform and graph filters, we begin by analyzing the reconstruction under the assumption that the signal of interest lies on a known subspace which depends on the supporting graph. We then move to blind setups and describe efficient algorithms to address the reconstruction. The last part of the talk reviews kernel-based and non-linear approaches, establishing relations with semi supervised learning and matrix completion approaches.

15.15-15.40: Iterative Chebyshev Polynomial Algorithm for Signal Denoising on Graphs

Cheng Cheng, Junzheng Jiang, Nazar Emirov & *Qiyu Sun*

Abstract: In this paper, we consider the inverse graph filtering process when the original filter is a polynomial of some graph shift on a simple connected graph. The Chebyshev polynomial approximation of high order has been widely used to approximate the inverse filter. In this paper, we propose an iterative Chebyshev polynomial approximation (ICPA) algorithm to implement the inverse filtering procedure, which is feasible to eliminate the restoration error even using Chebyshev polynomial approximation of lower order. We also provide a detailed convergence analysis for the ICPA algorithm and a distributed implementation of the ICPA algorithm on a spatially distributed network. Numerical results are included to demonstrate the satisfactory performance of the ICPA algorithm in graph signal denoising.

15.40-16.05: A non-commutative viewpoint on graph signal processing

Mahya Ghandehari, Dominique Guillot & Kristopher Hollingsworth

Abstract: The recent field of graph signal processing aims to develop analysis and processing techniques, designed for data that is best represented on irregular domains such as graphs. To this end, important notions of classical signal processing, such as smoothness, band-limitedness, and sampling, should be extended to the case of graph signals. One of the most fundamental concepts in classical signal processing is the Fourier transform. Recently, graph Fourier transform was defined as a generalization of the Fourier transform on Abelian groups, and many of its properties were investigated. However, a graph is usually the manifestation of a non-commutative structure; this can be easily seen in the case of the Cayley graph of a non-Abelian group. In this article, we investigate a new approach to develop concepts of Fourier analysis for graphs. Our point of view is inspired by the theory

of non-commutative harmonic analysis, and is founded upon representation theory of non-Abelian groups.

16.30-16.55: Clustering on Dynamic Graphs based on Total Variation

Peter Berger, Thomas Dittrich & Gerald Matz

Abstract: We consider the problem of multiclass clustering on dynamic graphs. At each time instant the proposed algorithm performs local updates of the clusters in regions of nodes whose cluster affiliation is uncertain and may change. These local cluster updates are carried out through semi-supervised multiclass total variation (TV) based clustering. The resulting optimization problem is shown to be directly connected to a minimum cut and thus very well suited to capture local changes in the cluster structure. We propose an ADMM based algorithm for solving the TV minimization problem. Its per iteration complexity scales linearly with the number of edges present in the local areas under change and linearly with the number of clusters. We demonstrate the usefulness of our approach by tracking several objects in a video with static background.

16.55-17.20: Enabling Prediction via Multi-Layer Graph Inference and Sampling

Stefania Sardellitti, Sergio Barbarossa & Paolo Di Lorenzo

Abstract: In this work we propose a novel method to efficiently predict dynamic signals over both space and time, exploiting the theory of sampling and recovery of band-limited graph signals. The approach hinges on a multi-layer graph topology, where each layer refers to a spatial map of points where the signal is observed at a given time, whereas different layers pertain to different time instants. Then, a dynamic learning method is employed to infer space-time relationships among data in order to find a band-limited representation of the observed signal over the multi-layer graph. Such a parsimonious representation is then instrumental to use sampling theory over graphs to predict the value of the signal on a future layer, based on the observations over the past graphs. The method is then tested on a real data-set, which contains the outgoing cellular data traffic over the city of Milan. Numerical simulations illustrate how the proposed approach is very efficient in predicting the calls activity over a grid of nodes at a given daily hour, based on the observations of previous traffic activity over both space and time.

17.20-17.45: Blue-Noise Sampling of Signals on Graphs

Alejandro Parada, Daniel Lau, Jhony Giraldo & Gonzalo Arce

Abstract: In the area of graph signal processing, a graph is a set of nodes arbitrarily connected by weighted links; a graph signal is a set of scalar values associated with each node; and sampling is the problem of selecting an optimal subset of nodes from which any graph signal can be reconstructed. For small graphs, finding the optimal sampling subset can be determined by looking at the graph's Fourier transform; however in some cases the spectral decomposition used to calculate the Fourier transform is not available. As such, this paper proposes the use of a spatial dithering, on the graph, as a way to conveniently find a statistically good, if not ideal, sampling - establishing that the best sampling patterns are the ones that are dominated by high frequency spectral components, creating a power spectrum referred to as blue-noise. The theoretical connection between blue-noise sampling on graphs and previous results in graph signal processing is also established, explaining the advantages of the proposed approach. Restricting our analysis to undirected and connected graphs, numerical tests are performed in order to compare the effectiveness of blue-noise sampling against other approaches.

17.45-18.10: Average sampling, average splines and Poincare inequality on combinatorial graphs

Isaac Pesenson

Abstract: In the setting of a weighted combinatorial finite or infinite countable graph G we introduce functional Paley-Wiener spaces $PW_\omega(L)$, $\omega > 0$, defined in terms of the spectral resolution of the combinatorial Laplace operator L in the space $L^2(G)$. It is shown that functions in certain $PW_\omega(L)$, $\omega > 0$, are uniquely defined by their averages over some families of "small" subgraphs which form a cover of G. Reconstruction methods for reconstruction of an $f \in PW_\omega(L)$, from appropriate set of its averages are introduced. One method is using language of Hilbert frames. Another one is using average variational interpolating splines which are constructed in the setting of combinatorial graphs.

14.50-17.45 A9 Amphi 2: Wavelets, Shearlets,...

14.50-15.15: Higher-dimensional wavelets and the Douglas-Rachford algorithm

Jeffrey Hogan, David Franklin & Matthew Tam

Abstract: We recast the problem of multiresolution-based wavelet construction in one and higher dimensions as a feasibility problem with constraints which enforce desirable properties such as compact support, smoothness and orthogonality of integer shifts. By employing the Douglas-Rachford algorithm to solve this feasibility problem, we generate one-dimensional and non-separable two-dimensional multiresolution scaling functions and wavelets.

15.15-15.40: Analytic and directional wavelet packets

Valery Zheludev

Abstract: The paper presents a versatile library of analytic and quas–analytic complex-valued wavelet packets (WPs) which originate from discrete splines of arbitrary orders. The real parts of these WPs are the regular spline-based orthonormal WPs. The imaginary parts are the so-called complementary orthonormal WPs, which, unlike the symmetric regular WPs, are antisymmetric. Tensor products of 1D quasi-analytic provide a diversity of 2D WPs oriented in multiple directions. For example, the set of fourth-level WPs comprise 256 different directions. The designed computational scheme enables extremely fast and easy design and implementation of the WP transforms.

15.40-16.05: Optimization in the construction of nearly cardinal and nearly symmetric wavelets

Neil Dizon, Jeffrey Hogan & Joseph Lakey

Abstract: We present two approaches to the construction of scaling functions and wavelets that generate nearly cardinal and nearly symmetric wavelets on the line. The first approach casts wavelet construction as an optimization problem by imposing constraints on the integer samples of the scaling function and its associated wavelet and with an objective function that minimizes deviation from cardinality or symmetry. The second method is an extension of the feasibility approach by Franklin, Hogan, and Tam to allow for symmetry by considering variables generated from uniform samples of the quadrature mirror filter, and is solved via the Douglas-Rachford algorithm.

16.30-16.55: Analysis of shearlet coorbit spaces in arbitrary dimensions using coarse geometry

René Koch & Hartmut Führ

Abstract: In order to analyze anisotropic information of signals, the shearlet transform has been introduced as class of directionally selective wavelet transform. One way of describing the approximation-theoretic properties of such generalized wavelet systems relies on coorbit spaces, i.e., spaces defined in terms of sparsity properties with respect to the system. In higher dimensions, there are several distinct possibilities for the definition of shearlet systems, and their approximation-theoretic properties are currently not well-understood. In this note, we investigate shearlet systems in higher dimensions derived from two particular classes of shearlet groups, the standard shearlet group and the Toeplitz shearlet group. We want to show that different groups lead to different approximation theories. The analysis of the associated coorbit spaces relies on an alternative description as decomposition spaces

that was recently established. For a shearlet group, this identification is based on a covering of the associated dual orbit induced by the shearlet group. The geometry of the sets in this covering is the determining factor for the associated decomposition space. We will see that the orbit can be equipped with a metric structure that encodes essential properties of this covering. The orbit map then allows to compare the geometric properties of coverings induced by different groups without the need to explicitly compute the respective coverings, which gets increasingly difficult for higher dimensions. This argument relies on a rigidity theorem which states that geometrically incompatible coverings lead to different decomposition spaces in almost all cases.

16-55-17.20: Trace Result of Shearlet Coorbit Spaces on Lines

Qaiser Jahan, Stephan Dahlke & Gabriele Steidl

Abstract: We study traces of certain subspaces of shearlet coorbit spaces on lines in R^2 which extends the results for horizontal and vertical lines from

S. Dahlke, S. Häuser, G. Steidl, and G. Teschke, *Shearlet coorbit spaces: traces and embeddings in higher dimensions.* Monatsh. Math., 169(1), 15–23, (2013).

14.50-16.05 A9 Amphi 3: Super-Resolution.

14.50-15.15: The dual approach to non-negative super-resolution: impact on primal reconstruction accuracy

Bogdan Toader, *Stéphane Chrétien* & Andrew Thompson

Abstract: We study the problem of super-resolution, where we recover the locations and weights of non-negative point sources from a few samples of their convolution with a Gaussian kernel. It has been recently shown that exact recovery is possible by minimising the total variation norm of the measure. An alternative practical approach is to solve its dual. In this paper, we study the stability of solutions with respect to the solutions to the dual problem. In particular, we establish a relationship between perturbations in the dual variable and the primal variables around the optimiser. This is achieved by applying a quantitative version of the implicit function theorem in a non-trivial way.

15.15-15.40: Conditioning of restricted Fourier matrices and super-resolution of MUSIC

Wenjing Liao & Weilin Li

Abstract: This paper studies stable recovery of a collection of point sources from its noisy $M+1$ low-frequency Fourier coefficients. We focus on the super-resolution regime where the minimum separation of the point sources is below $1/M$. We propose a separated clumps model where point sources are clustered in far apart sets, and prove an accurate lower bound of the Fourier matrix with nodes restricted to the source locations. This estimate gives rise to a theoretical analysis on the super-resolution limit of the MUSIC algorithm.

15.40-16.05: Iterative Discretization of Optimization Problems Related to Superresolution

Axel Flinth & Pierre Armand Weiss

Abstract: We study an iterative discretization algorithm for solving optimization problems regularized by the total variation norm over the space of Radon measures on a bounded subset of$\mathbb{R}^d$. Our main motivation to study this problem is the recovery of sparse atomic measures from linear measurements. Under reasonable regularity conditions, we arrive at a linear convergence rate guarantee.

14.50-17.45 A9 Amphi 3: Sampling and Fourier analysis.

16.30-16.55: On the Reconstruction of a Class of Signals Bandlimited to a Disc

Ahmed Zayed

Abstract: Signal reconstruction is one of the most important problems in signal processing and sampling theorems are one of the main tools used for such reconstructions. There is a vast literature on sampling in one and higher dimensions of bandlimited signals. Because the sampling formulas and

points depend on the geometry of the domain on which the signals are confined, explicit representations of the reconstruction formulas exist mainly for domains that are geometrically simple, such as intervals or parallelepiped symmetric about the origin. In this talk we derive sampling theorem for the reconstruction of signals that are bandlimited to a disc centered at the origin. This will be done for a more general class of signals than those that are bandlimited in the Fourier transform domain. The sampling points are related to the zeros of the Bessel function.

16.55-17.20: The Solvability Complexity Index of Sampling-based Hilbert Transform Approximations

Volker Pohl & Holger Boche

Abstract: This paper determines the solvability complexity index (SCI) and a corresponding tower of algorithms for the computational problem of calculating the Hilbert transform of a continuous function with finite energy from its samples. It is shown that the SCI of these algorithms is equal to 2 and that the SCI is independent on whether the calculation is done by linear or by general (i.e. linear and/or non-linear) algorithms.

17.20-17.45: The Convolution Word is Tied to the Exponential Kernel Transforms. What is a Parallel Expression for the Other Transforms?

Abdul Jerri

Abstract: Convolution products are very useful in computations involving exponential kernel transforms, such as the Fourier and Laplace transforms. The feasibility of this method is due to the important property $e^{\alpha x}e^{\beta x} = e^{(\alpha+\beta)x}$, that is behind the simple form of the convolution product. Convolution also has the visual property, as it means bending together of the functions. For non-exponential kernel transforms, such as the Hankel transform, the analytical expressions of the Inverse Transform of Two Transforms Product (ITTTP) is quite complicated for use in practical analytical computations. Such difficulty is, mainly, due to the absence of the previously mentioned exponential function property. This is illustrated with a variety of well-known integral transforms. Also, such difficulty is supported by testimonials of experts in the field, such as Ruell Churchill and Ian Sneddon. Therefore, there is a need to return to basics numerical integration, according to the definition of the ITTTP. This is our most recent experience, in cooperation with M. Kamada, in trying to compute the general transform hill functions $\psi_{R+1}(x)$ associated with the Bessel function kernel, that the speaker had introduced in 1983. They are defined as the R-times J_N kernel "convolution parallel" of the gate function.

Friday Morning.

8:30 - 9:30 A22 - Wegener: Massimo Fornasier.

Robust and efficient identification of neural networks

Abstract: Identifying a neural network is an NP-hard problem in general. In this talk we address conditions of exact identification of one and two hidden layer totally connected feed forward neural networks by means of a number of samples, which scales polynomially with the dimension of the input and network size. The exact identification is obtained by computing second order approximate strong or weak differentials of the network and their unique and stable decomposition into nonorthogonal rank-1 terms. The procedure combines several novel matrix optimization algorithms over the space of second order differentials. As a byproduct we introduce a new whitening procedure for matrices, which allows the stable decomposition of symmetric matrices into nonorthogonal rank-1 decompositions, by reducing the problem to the standard orthonormal decomposition case. We show that this algorithm practically achieve information theoretical recovery bounds. We illustrate the results by several numerical experiments.

This is a joint work with Ingrid Daubechies, Timo Klock, Michael Rauchensteiner, and Jan Vybíral.

10.00-12.05 A22 - Wegener: Wavelets, Shearlets,... 10.00-10.25: Robust One-bit Compressed Sensing With Manifold Data

Mark Iwen, Sjoerd Dirksen, Johannes Maly & Sara Krause-Solberg

Abstract: We study one-bit compressed sensing for signals on a low-dimensional manifold. We introduce two computationally efficient reconstruction algorithms that only require access to a geometric multi-resolution analysis approximation of the manifold. We derive rigorous reconstruction guarantees for these methods in the scenario that the measurements are subgaussian and show that they are robust with respect to both pre- and post-quantization noise. Our results substantially improve upon earlier work in this direction.

10.00-10.25: One-Bit Sensing of Low-Rank and Bisparse Matrices

Simon Foucart & Laurent Jacques

Abstract: This note studies the worst-case recovery error of low- rank and bisparse matrices as a function of the number of one-bit measurements used to acquire them. First, by way of the concept of consistency width, precise estimates are given on how fast the recovery error can in theory decay. Next, an idealized recovery method is proved to reach the fourth-root of the optimal decay rate for Gaussian sensing schemes. This idealized method being impractical, an implementable recovery algorithm is finally proposed in the context of factorized Gaussian sensing schemes. It is shown to provide a recovery error decaying as the sixth-root of the optimal rate.

10.50-11.15: Robust 1-Bit Compressed Sensing via Hinge Loss Minimization

Alexander Stollenwerk & Martin Genzel

Abstract: We study the problem of estimating a structured high-dimensional signal $x_0 \in \mathbb{R}^n$ from noisy 1-bit Gaussian measurements. Our recovery approach is based on a simple convex program which uses the hinge loss function as data fidelity term. While such a risk minimization strategy is typically applied in classification tasks, its capacity to estimate a specific signal vector is largely unexplored. In contrast to other popular loss functions considered in signal estimation, which are at least locally strongly convex, the hinge loss is just piecewise linear, so that its "curvature energy" is concentrated in a single point. It is therefore somewhat unexpected that we can still prove very similar types of recovery guarantees for the hinge loss estimator, even in the presence of strong noise. More specifically, our error bounds show that stable and robust reconstruction of x_0 can be achieved with the optimal oversampling rate $O(m^{-1/2})$ in terms of the number of measurements m. Moreover, we permit a wide class of structural assumptions on the ground truth signal, in the sense that x_0 can belong to an arbitrary bounded convex set $K \subset \mathbb{R}^n$. For the proofs of our main results we invoke an

adapted version of Mendelson's small ball method that allows us to establish a quadratic lower bound on the error of the first order Taylor approximation of the empirical hinge loss function.

11.15-11.40: High-performance quantization for spectral super-resolution

Sinan Gunturk & Weilin Li

Abstract: We show that the method of distributed noise-shaping beta-quantization offers superior performance for the problem of spectral super-resolution with quantization whenever there is redundancy in the number of measurements. More precisely, if the (integer) oversampling ratio λ is such that $\lfloor M/\lambda \rfloor - 1 \geq 4/\Delta$, where M denotes the number of Fourier measurements and Δ is the minimum separation distance associated with the atomic measure to be resolved, then for any number $K \geq 2$ of quantization levels available for the real and imaginary parts of the measurements, our quantization method guarantees reconstruction accuracy of order $O(\lambda K^{-\lambda/2})$, up to constants which are independent of K and λ. In contrast, memoryless scalar quantization offers a guarantee of order $O(K^{-1})$ only.

11.40-12:05: On one-stage recovery for $\Sigma\Delta$-quantized compressed sensing

Ozgur Yilmaz & Arman Ahmadieh

Abstract: Compressed sensing is a signal acquisition paradigm that can be used to simultaneously acquire and reduce dimension of signals in high dimension that admit sparse representations with respect to an appropriate basis or frame. When such a signal is acquired according to the principles of compressed sensing, the resulting measurements still take on values in the continuum. In today's "digital" world, a subsequent quantization step, where these measurement values are replaced with elements from a finite set is crucial. After briefly reviewing the literature on quantization for compressed sensing, we will focus on one of the approaches that yield efficient quantizers for compressed sensing: $\Sigma\Delta$ quantization, followed by a one-stage reconstruction method that is based on solving a tractable convex optimization problem. This approach was developed by Wang, Saab, and Yilmaz with theoretical error guarantees in the case of sub-Gaussian matrices. We propose two alternative approaches that extend the results of that paper to a wider class of measurement matrices. These include (certain unitary transforms of) partial bounded orthonormal systems and deterministic constructions based on chirp sensing matrices.

10.00-12.05 A22 Edison: Fourier Analysis.

10.00-10.25: Riesz bases of exponentials for partitions of intervals

David Walnut, Goetz E. Pfander & Shauna Revay

Abstract: For a partition of $[0, 1]$ with nodes $0 = a_0 < a_1 < \cdots < a_{n-1} < a_n = 1$, we construct a partition of $\mathbb{Z}$, $\Lambda_1, \Lambda_2, \ldots, \Lambda_n$ such that $\mathcal{E}(\Lambda_j)$ is a Riesz basis for $L^2[a_{j-1}, a_j]$. Our construction also guarantees that $\mathcal{E}\left(\bigcup_{j=1}^{k} \Lambda_j\right)$ is a Riesz basis for $L^2[0, a_k]$, and $\mathcal{E}\left(\bigcup_{j=k+1}^{n} \Lambda_j\right)$ is a Riesz basis for $L^2[a_k, 1]$.

10.25-10.50: Computability of the Fourier Transform and ZFC

Holger Boche & Ullrich J. Mönich

Abstract: In this paper we study the Fourier transform and the possibility to determine the binary expansion of the values of the Fourier transform in the Zermelo–Fraenkel set theory with the axiom of choice included (ZFC). We construct a computable absolutely integrable bandlimited function with continuous Fourier transform such that ZFC (if arithmetically sound) cannot determine a single binary digit of the binary expansion of the Fourier transform at zero. This result implies that ZFC cannot determine for every precision goal a rational number that approximates the Fourier transform at zero. Further, we discuss connections to Turing computability.

10.50-11.15: Rearranged Fourier Series and Generalizations to Non-Commutative Groups

Armenak Petrosyan, Keaton Hamm & Benjamin Hayes

Abstract: It is well-known that the Fourier series of continuous functions on the torus are not always uniformly convergent. However, P. L. Ulyanov proposed a problem: *can we permute the Fourier series of each individual continuous function in such a way as to guarantee uniform convergence of the rearranged Fourier series?* This problem remains open, but nonetheless a rather strong partial result was proved by S. G. Revesz which states that for every continuous function there exists a subsequence of rearranged partial Fourier sums converging to the function uniformly. We give several new equivalences to Ulyanov's problem in terms of the convergence of the rearranged Fourier series in the strong and weak operator topologies on the space of bounded operators on $L^2(\mathbb{T})$. This new approach gives rise to several new problems related to rearrangement of Fourier series. We also consider Ulyanov's problem and Revesz's theorem for reduced C^*-algebras on discrete countable groups.

11.15-11.40: Deterministic guarantees for L^1-reconstruction: A large sieve approach with geometric flexibility

Michael Speckbacher & Luís Daniel Abreu

Abstract: We present estimates of the p-concentration ratio for various function spaces on different geometries including the line, the sphere, the plane, and the hyperbolic disc, using large sieve methods. Thereby, we focus on L^1-estimates which can be used to guarantee the reconstruction from corrupted or partial information.

11.40-12.05: A Clifford Construction of Multidimensional Prolate Spheroïdal Wave Functions

Hamed Baghal Ghaffari, Jeffrey Hogan & Joseph Lakey

Abstract: We investigate the construction of multidimensional prolate spheroidal wave functions using techniques from Clifford analysis. The prolates defined to be eigenfunctions of a certain differential operator and we propose a method for computing these eigenfunctions through expansions in Clifford-Gegenbauer polynomials. It is shown that the differential operator commutes with a time-frequency limiting operator defined relative to balls in n-dimensional Euclidean space.

Friday Afternoon.

13.30-14.20 A22 Wegener: Deep Learning. 13.30-13.55: Approximation in $L^p(\mu)$ with deep *ReLU* neural networks

Felix Voigtlaender & Philipp Petersen

Abstract: We discuss the expressive power of neural networks which use the non-smooth *ReLU* activation function $\rho(x) = \max\{0, x\}$ by analyzing the approximation theoretic properties of such networks. The existing results mainly fall into two categories: approximation using *ReLU* networks with a fixed depth, or using *ReLU* networks whose depth increases with the approximation accuracy. After reviewing these findings, we show that the results concerning networks with fixed depth—which up to now only consider approximation in $L^p(\lambda)$ for the Lebesgue measure λ—can be generalized to approximation in $L^p(\mu)$, for any finite Borel measure μ. In particular, the generalized results apply in the usual setting of statistical learning theory, where one is interested in approximation in $L^2(\mathbb{P})$, with the probability measure $\mathbb{P}$ describing the distribution of the data.

13.55-14.20: Modeling Global Dynamics from Local Snapshots with Deep Generative Neural Networks

Scott Gigante, David Van Dijk, Kevin Moon, Alexander Strzalkowski, Guy Wolf & Smita Krishnaswamy

Abstract: Complex high dimensional stochastic dynamic systems arise in many applications in the natural sciences and especially biology. However, while these systems are difficult to describe analytically, "snapshot" measurements that sample the output of the system are often available. In order to model the dynamics of such systems given snapshot data, or local transitions, we present a deep neural network framework we call Dynamics Modeling Network or DyMoN. DyMoN is a neural network framework trained as a deep generative Markov model whose next state is a probability distribution based on the current state. DyMoN is trained using samples of current and nextstate pairs, and thus does not require longitudinal measurements. We show the advantage of DyMoN over shallow models such as Kalman filters and hidden Markov models, and other deep models such as recurrent neural networks in its ability to embody the dynamics (which can be studied via perturbation of the neural network), generate longitudinal hypothetical trajectories, and denoise measurement artifacts. We perform three case studies in which we apply DyMoN to different types of biological systems and extract features of the dynamics in each case by examining the learned model.

13.30-14.20 A22 Edison: Inverse problems. 13.30-13.55: Convergence Rates for Hölder-Windows in Filtered Back Projection

Matthias Beckmann & Armin Iske

Abstract: In this paper we consider the approximation of bivariate functions by using the well-established filtered back projection (FBP) formula from computerized tomography. We establish error estimates and convergence rates for the FBP reconstruction method for target functions f from a Sobolev space $H^\alpha(\mathbb{R}^2)$ of fractional order $\alpha > 0$, where we bound the FBP reconstruction error with respect to the weaker norms of the Sobolev spaces $H^\sigma(\mathbb{R}^2)$, for $0 \le \sigma \le \alpha$. By only assuming Hölder continuity of the low-pass filter's window function, the results of this paper generalize previous of our findings.

13.55-14.20: Dynamical Sampling with a Burst-like Forcing Term

Akram Aldroubi, Longxiu Huang, Keri Kornelson & Ilya Krishtal

Abstract: In this paper we consider the problem of recovery of a burst-like forcing term in the framework of dynamical sampling. We introduce the notion of a sensing limit of a collection of samples with respect to a semigroup and indicate its fundamental role in the solvability of the problem.

14:30 - 15:30 A22 - Wegener: Rémi Gribonval.

Learning from moments - Large-scale learning with the memory of a goldfish

Abstract: Inspired by compressive sensing, Compressive Statistical Learning allows drastic volume and dimension reduction when learning from large/distributed/streamed data collections. The principle is to exploit random projections to compute a low-dimensional (nonlinear) sketch (a vector of random empirical generalized moments), in essentially one pass on the training collection. Sketches of controlled size have been shown to capture the information relevant to certain learning tasks such as unsupervised clustering, Gaussian mixture modeling or PCA. As a proof of concept, more than a thousand hours of speech recordings can be distilled to a sketch of only a few kilo-bytes that captures enough information to estimate a Gaussian Mixture Model for speaker verification. The talk will highlight the main features of this framework, including statistical learning guarantees —obtained using tools from randomized low-dimensional projections and compressive sensing—, differential privacy guarantees, and open challenges.

Presentations by author

E

	We am
Ahmet M. Elbir	**Tu am**
Dennis Elbrächter	**Tu am**
Yonina C. Eldar	**Tu am**
Nazar Emirov	**Th pm**
Ujué Etayo	**Tu am**

F

Markus Faulhuber	**Tu am**
Matthew Fickus	**Mo pm**
Frank Filbir	**Tu pm**
Julien Flamant	**Tu am**
Axel Flinth	**Th pm**
Daniel Forger	**Tu pm**
Simon Foucart	**Fr am**
Massimo Fornasier	**Fr am**
David Franklin	**Th pm**
Rong Fu	**Tu am**
Hartmut Führ	**Th pm**

G

Martin Genzel	**Fr am**
Mahya Ghandehari	**Th pm**
Ali GhaziZadeh	**P20**
Joydeep Ghosh	**Th am**
Scott Gigante	**P1** **Fr pm**
Anna Gilbert	**Tu am**
Jhony Giraldo	**Th pm**
Tom Goldstein	**We am**
Olga Graf	**P18** **Tu pm** **Th am**
Rémi Gribonval	**Fr pm**
Philipp Grohs	**Tu am**
Nadja Gruber	**P2**
Dominique Guillot	**Th pm**
Suriya Gunasekar	**Tu pm**
Sinan Gunturk	**Fr am**

H

Jamie Haddock	**P17**
Antti Haimi	**Tu am**
Markus Haltmeier	**P2** **Tu am**
Keaton Hamm	**P16** **Fr am**
Bin Han	**Tu pm**
Paul Hand	**We am**
Adrien Hardy	**Tu am**
Ofer Harel	**Th am**
Hari Hari Krishan Malhotra	**P6**
Marzieh Hasannasab-jaldehbakhani	**Tu pm**
Sascha Hauch	**Tu am**
Benjamin Hayes	**Fr am**
Chinmay Hegde	**Th am**
Miguel Heredia Conde	**P14**
Jeffrey Hogan	**We am** **Th pm** **Fr am**
Kristopher Hollingsworth	**Th pm**
Daniel Hsu	**Tu pm**
Longxiu Huang	**P16** **Fr pm**
Yitong Huang	**Tu pm**
Kevin Huynh	**Mo am**

I

Jérôme Idier	**P15**
Armin Iske	**Fr pm**
Elvin Isufi	**We am**
Joseph W. Iverson	**Mo pm**
Mark Iwen	**Mo am**
	Fr am

J

Laurent Jacques	**Fr am**
Qaiser Jahan	**Th pm**
Philippe Jaming	**Mo am**
	Th am
Arnulf Jentzen	**Tu am**
Halyun Jeong	**Mo pm**
Jerri Abdul	**Th pm**
Junzheng Jiang	**Th pm**
Peter Jung	**Mo am**
Marius Junge	**Mo am**

K

Alihan Kaplan	**P9**
Santhosh Karnik	**Mo pm**
Karim Kellay	**Mo am**
Zeljko Kereta	**Mo pm**
Emily King	**Mo pm**
Andi Kivinukk	**Th am**
René Koch	**Th pm**
Günther Koliander	**Tu am**
Keri Kornelson	**Fr pm**
Jelena Kovačević	**We am**
Oluwasanmi Koyejo	**Th am**
Felix Krahmer	**Tu pm**
	Th am
Sara Krause-Solberg	**Tu pm**
	Fr am
Smita Krishnaswamy	**P1**
	Fr pm
Ilya Krishtal	**Fr pm**
Aleksander Krivoshein	**P7**
Christian Kümmerle	**Mo am**
Dmitriy Kunisky	**Tu pm**
Gitta Kutyniok	**Tu am**
	We am

L

Chun-Kit Lai	**Mo am**
Joseph Lakey	**We am**
	Th pm
	Fr am
Thomas Joseph Lane	**Mo am**
Daniel Lau	**Th pm**
Elena Lebedeva	**P7**
Dae Gwan Lee	**Mo am**
Kiryung Lee	**Mo am**
Jakob Lemvig	**Mo am**
Oscar Leong	**We am**
Ron Levie	**We am**
Po-Nan Li	**Mo am**
Weilin Li	**Fr am**
Xiaowei Li	**Mo pm**
Liao Wenjing	**Th pm**
Kung-Ching Lin	**P3**
Friedrich Littmann	**Mo am**
Otmar Loffeld	**P14**
Eric Lybrand	**Mo am**

M

Siyuan Ma	**Tu pm**
Jan Macdonald	**Tu am**
Mark E. Magsino	**Mo pm**
Johannes Maly	**Fr am**
Soumik Mandal	**Tu pm**
Antonio G. Marques	**Th pm**
Gerald Matz	**Th pm**
Oleh Melnyk	**Tu pm**
Urbashi Mitra	**Th am**
Dustin G. Mixon	**Mo pm**
Ursula Molter	**We am**
Ullrich J. Mönich	**Fr am**
Matteo Monti	**P23**
Kevin Moon	**P1**
	Fr pm
Satish Mulleti	**Tu am**

N

Alireza Naderi	**Th am**
Valeriya Naumova	**Mo pm**
Nazar Emirov	**Th pm**
Deanna Needell	**Mo am**
Felipe Negreira	**Th am**
Aaron Nelson	**Mo am**
Thanh Nguyen	**Th am**
Thi-Thanh Nguyen	**P15**
Kamilla H. Nielsen	**Mo am**

O-P-Q

Daniel Obmann	**Tu am**
Samet Oymak	**Tu pm**
Alejandro Parada	**Th pm**
Josiah Park	**Tu pm**
Christian Parkinson	**Mo am**
Hans Parshall	**Mo pm**
Rolando Perez III	**Mo am**
Victoria Paternostro	**Tu pm**
Philipp Petersen	**Tu am**
	Fr pm
Armenak Petrosyan	**Fr am**
Goetz E Pfander	**Mo am**
	Fr am
Friedrich Philipp	**Mo am**
Federico Piazzon	**P13**
Yaniv Plan	**Mo pm**
	Tu am
Volker Pohl	**P9**
	Mo am
Jürgen Prestin	**P7**
Saeed Qaisar	**P 4**

R

Trivellore E. Raghunathan	**Th am**
Shristi Rajbamshi	**Tu am**
Mones Raslan	**Tu am**
Saeed Razavi-Kia	**P21,P22**
Shauna Revay	**Fr am**
Noli Reyes	**P11**
Justin K. Romberg	**Mo am**
Mo pm	
José Luis Romero	**Tu am**
	We am
Lorenzo Rosasco	**Mo pm**
Dominik Rzepka	**Tu am**

S

Rayan Saab	**Mo am**
Anna Saksa	**Th am**
Palina Salanevich	**P10**
	We am
Moshe Salhov	**P19**
Stefania Sardellitti	**Th pm**
Courtney Schmitt	**Mo pm**
Johannes Schwab	**Tu am**
Fahad Shamshad	**P8**
Rakshith Sharma Srinivasa	**Mo am**
Mahdi Soltanolkotabi	**We am**
Akshay Soni	**Th am**
Charles Soussen	**P15**
Michael Speckbacher	**Fr am**
Jay S. Stanley III	**P1**
Gabriele Steidl	**Th pm**
Alexander Stollenwerk	**Fr am**
Alexander Strzalkowski	**Fr pm**
Christoph Studer	**We am**
Abdulhamit Subasi	**P4**
Ju Sun	**Mo am**
Qiyu Sun	**Th pm**

T

Matthew Tam	**Th pm**
Gert Tamberg	**P18**
Yuichi Tanaka	**We am**
Georg Tauböck	**Tu am**
Matus Telgarsky	**Tu pm**
Nguyen T. Thao	**Tu am**
Thompson Andrew	**Th pm**
Toader Bogdan	**Th pm**
Hoang A. Tran	**P5**

U-V

Michael Unser	**Th am**
Louie John Vallejo	**P11**
David Van Dijk	**P1**
	Fr pm
Pierre Vandergheynst	**Mo am**
Rohan Varma	**We am**
Lalit K. Vashisht	**P6**
Gino Angelo Velasco	**Mo am**
Cláudio M. Verdun	**Mo am**
Marco Vianello	**P13**
Stefano Vigogna	**Mo pm**
Felix Voigtlaender	**Mo am**
	Tu am
	Fr pm
Vladislav Voroninski	**We am**
Ngan Vu	**P1**

W-Z

Olivia Walch	**Tu pm**
Stephan Wäldchen	**Tu am**
David Walnut	**Fr am**
Eric S. Weber	**Mo am**
Clayton Webster	**P5**
Pierre Armand Weiss	**Th pm**
Matthias Wellershoff	**Tu pm**
Guy Wolf	**P1**
	Fr pm
Yishu Xue	**Th am**
Ozgur Yilmaz	**Mo pm**
	Tu am
	Fr am
Hojatollah Zamani	**P21,P22**
Greg Zanotti	**Tu am**
Ahmed Zayed	**Th pm**
Valery Zheludev	**Th pm**
Xiaosheng Zhuang	**Tu pm**