2. International Matheon Conference on

Compressed Sensing and its Applications

December 7-11, 2015

Technische Universität Berlin

Conference Program

For more information visit us on:

www3.math.tu-berlin.de/csa2015

Time	Monday	Tuesday	Wednesday	Thursday	Friday
8.00-8.45	Reg. From 7.30	Registration			
8.45-9.00	Opening Remarks				
9.00-10.00	Elad	Ward	Montanari	Eldar	Strohmer
10.00-10.30	Coffee				
10.30-11.05	Soltanolkotabi	Müller	Krahmer	Maggioni	Schniter
11.05-11.40	Caramanis	Schnass	Bodmann	Adcock	Mixon
11.40-12.15	Chandrasekaran	Gribonval	Ehler	Davies	Final Remarks
12.15-14.00	Lunch				
14.00-15.00	Vershynin	Rauhut	Excursion	Chen	
15.00-15.30	Coffee			Coffee	
15.30-16.05	Tanner	Poster Session		Poster Session	
16.05-16.40	Schneider				
16.40-17.45					
19.00-		Dinner			

Welcome

After our first successful workshop in 2013 it is our great pleasure to welcome you at the Technische Universität Berlin to the *2. International* MATHEON *Conference on Compressed Sensing and its Applications.* This booklet has been put together to provide you with all the relevant information on the workshop and to aid you during your stay in Berlin.

We would like to express our gratitude to all Plenary and Invited Speakers for accepting our invitation, as well as to all participants for visiting the Technische Universität Berlin to join this conference. We also gratefully acknowledge the support by the Deutsche Forschungsgemeinschaft (DFG), the DFG Research Center MATHEON "Mathematics for key technologies" in Berlin, the Einstein Center for Mathematics Berlin, the Alexander von Humboldt Foundation, and the Technische Universität Berlin.

No conference would be possible without a team of dedicated volunteers, and we gratefully acknowledge the help of all members of the Applied Functional Analysis Group at the Technische Universität Berlin:

Axel Flinth	Jackie Ma
Martin Genzel	Maximilian März
Mijail Guillemard	Philipp Petersen
Anja Hedrich	Friedrich Philipp
Sandra Keiper	Mones Raslan
Anton Kolleck	Martin Schäfer
Maximilian Leitheiser	Yizhi Sun

If you have any questions, please feel free to come to the registration desk, which will be open each day from 8:00 AM until the end of the lectures/poster session, or contact anyone else from the team whose members are identifiable by a green name tag.

We now wish you an exciting conference, which we hope will bring you fruitful scientific exchange and many new contacts.

Holger Boche, Guiseppe Caire, Robert Calderbank,
Gitta Kutyniok, and Rudolf Mathar

Program Matheon Workshop CSA2015

All talks will take place in H 3005

Monday, 7.12. *7.30 – 8.45* *Registration*
8.45 – 9.00 *Welcome Remarks*

9.00 – 10.00 **Michael Elad** *(Technion – Israel Institute of Technology, Israel)*
The Dichotomy between Global Processing and Local Modelling
10.00 – 10.30 *Coffee Break*
10.30 – 11.05 Mahdi Soltanolkotabi *(University of California, USA)*
Structured Signal Recovery without the Shackles of Convexity
11.05 – 11.40 Constantine Caramanis *(University of Texas at Austin, USA)*
Fast Binary Embedding
11.40 – 12.15 Venkat Chandrasekaran *(California Institute of Technology, USA)*
Finding Planted Subgraphs via the Schur-Horn Relaxation

12.15 – 14.00 *Lunch Break*

14.00 – 15.00 **Roman Vershynin** *(University of Michigan, USA)*
Recovering Hidden Structures in Sparse Networks
15.00 – 15.30 *Coffee Break*
15.30 – 16.05 Jared Tanner *(University of Oxford, UK)*
Parallell-l_0, a Fully Parallel Algorithm for Combinatorial Compressed Sensing
16.05 – 16.40 Reinhold Schneider *(Technische Universität Berlin, Germany)*
Tensor Recovery for Hierarchical Tensors (HT/TT)

Tuesday, 8.12. *8.00 – 9.00* *Registration*

9.00 – 10.00 **Rachel Ward** *(University of Texas at Austin, USA)*
Geometric Clustering via Convex Optimization and Rounding
10.00 – 10.30 *Coffee Break*
10.30 – 11.05 Klaus Müller *(Technische Universität Berlin, Germany)*
Machine Learning and Sparsity
11.05 – 11.40 Karin Schnass *(University of Innsbruck, Austria)*
Dictionary Learning from Incomplete Data
11.40 – 12.15 Rémi Gribonval *(Centre de Recherche INRIA Rennes - Bretagne Atlantique, France)*
Projections, Learning and Sparsity for Efficient Data Processing

12.15 – 14.00 *Lunch Break*

14.00 – 15.00 **Holger Rauhut** *(RWTH Aachen, Germany)*
Analysis of Compressive Sensing in Radar
15.00 – 15.30 *Coffee Break*

15.30 – 17.45 Poster Session *(Lichthof)*

19.00 – **Conference Dinner**

<u>Wednesday, 9.12.</u> *8.00 - 9.00* *Registration*

9.00 – 10.00 **Andrea Montanari** *(Stanford University, USA)*
Phase Transitions in Semidefinite Relaxations
10.00 – 10.30 *Coffee Break*
10.30 – 11.05 Felix Krahmer *(Technische Universität München, Germany)*
On Empirical Chaos Processes and Their Application in Blind Deconvolution
11.05 – 11.40 Bernhard Bodmann *(University of Houston, USA)*
Phase Retrieval with Over- and Under-Sampling
11.40 – 12.15 Martin Ehler (*University of Vienna, Austria)*
Grassmannian Manifolds and Their Interrelations

12.15 – 14.00 *Lunch Break*

14.00 – 17.15 **Excursion**

<u>Thursday, 10.12.</u> *8.00 – 9.00* *Registration*

9.00 – 10.00 **Yonina Eldar** *(Technion – Israel Institute of Technology, Israel)*
Sub-Nyquist Sampling without Sparsity and Phase Retrieval
10.00 – 10.30 *Coffee Break*
10.30 – 11.05 Mauro Maggioni *(Duke University, USA)*
Multiscale Geometric Methods for Statistical Learning and Dictionaries for Data and Images
11.05 – 11.40 Ben Adcock *(Simon Fraser University, Canada)*
Function Interpolation and Compressed Sensing
11.40 – 12.15 Mike Davies *(University of Edinburgh, UK)*
Quantitative MRI Using Model-Based Compressed Sensing

12.15 – 14.00 *Lunch Break*

14.00 – 15.00 **Yuxin Chen** *(Stanford University, USA)*
Modern Optimization meets Physics: Recent Progress on the Phase Retrieval Problem
15.00 – 15.30 *Coffee Break*

15.30 – 17.45 Poster Session *(Math Building, 1st floor)*

<u>Friday, 11.12.</u> *8.00 – 9.00* *Registration*

9.00 – 10.00 **Thomas Strohmer** *(University of California at Davis, USA)*
Blind Deconvolution Meets Blind Demixing: Convexity and the Internet-of-Things
10.00 – 10.30 *Coffee Break*
10.30 – 11.05 Phil Schniter *(Ohio State University, USA)*
Iteratively Reweighted l_1 Approaches to Sparse Composite Regularization
11.05 – 11.40 Dustin Mixon *(AFIT, USA)*
Probably Certifiably Correct k-means Clustering

11.40 – 12.00 Final Remarks

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Monday Plenary Talks

The Dichotomy between Global Processing and Local Modeling

Michael Elad

Technion - Israel Institute of Technology, Israel

09:00–10:00

Recent work in image processing repeatedly shows highly efficient reconstruction algorithms that lean on modeling of small overlapping patches. Such methods impose a local model in order to regularize a global inverse problem. Why does this work so well? Does this leave room for improvements? What does a local model imply globally on the unknown signal? In this talk we will start from algorithmic attempts that aim to understand this dichotomy in order to narrow the global-local gap. Gradually, we will turn the discussion to a theoretical point of view that provides a deeper understanding of such local models, and their global implications. The talk is based on joint work with Dmitry Batenkov, Jeremias Sulam, Vardan Papyan, and Yaniv Romano.

Recovering Hidden Structures in Sparse Networks

Roman Vershynin

University of Michigan, USA

14:00–15:00

Most big real-world networks (social, technological, biological) are sparse. Most of networks have noticeable structure, for example clusters (communities) and hubs. When and how can a hidden structure be recovered from a sparse network? Known approaches to this problem come from a variety of disciplines – probability, combinatorics, physics, statistics, optimization, information theory, etc. We will focus on the recently developed probabilistic approaches motivated by sparse recovery, where a network is regarded as a random measurement of the hidden structure.

Monday Invited Talks

Morning Session

10:30–11:05 **Structured Signal Recovery without the Shackles of Convexity**
Mahdi Soltanolkotabi, University of California, Berkeley, USA

Many problems in science and engineering ask for solutions to underdetermined systems of linear equations. The last decade has witnessed a flurry of activity in understanding when and how it is possible to solve such problems using convex/greedy schemes. Structured signal recovery via convex methods has arguably revolutionized signal acquisition, enabling signals to be measured with remarkable fidelity using a small number of measurements. Despite many success stories, in this talk I will argue that over insistence on convex methods has stymied progress in some application domains. I will discuss my ongoing research efforts to "unshackle" structured signal recovery from the confines of convexity opening the door for new applications. In particular, I will present a unified theoretical framework for sharply characterizing the convergence rates of various (non-)convex iterative schemes for solving such problems. Time permitting, I will also discuss problem domains where carefully designed non-convex techniques are effective but convex counterparts are known to fail or yield suboptimal results. This is based on joint work with collaborators who shall be properly introduced during the talk.

11:05–11:40 **Fast Binary Embedding**
Constantine Caramanis, University of Texas at Austin, USA

Given an arbitrary set of N distinct points on the p-dimensional sphere, our goal is to encode each point using m-dimensional binary strings such that we can reconstruct their geodesic pairwise distance up to δ-uniform distortion. Existing binary embedding algorithms either lack theoretical guarantees or have running time as high as $O(mp)$. In this talk, we discuss:

1. a lower bound that shows any binary embedding requires $m{=}\Omega(\log N/\delta^2)$ bits
2. a novel fast binary embedding algorithm with provably optimal bit complexity $m{=}O(\log N/\delta^2)$ and near linear running time $O(p \log p)$
3. an analytic result about embedding a general (even infinite size) set of points on the sphere.

Joint work with Xinyang Yi and Eric Price.

11:40–12:15 **Finding Planted Subgraphs via the Schur-Horn Relaxation**
Venkat Chandrasekharan, California Institute of Technology, USA

Extracting structured planted subgraphs from large graphs is a fundamental question that arises in a range of application domains. We describe a computationally tractable approach based on convex optimization to recover certain families of structured graphs that are embedded in larger graphs containing spurious edges. Our method relies on tractable semidefinite descriptions of majorization inequalities on the spectrum of a matrix, and we give conditions on the eigenstructure of a planted graph in relation to the noise level under which our algorithm succeeds. (Joint work with Utkan Candogan.)

15:30–16:05 **Parallel-ℓ_0, a Fully Parallel Algorithm for Combinatorial Compressed Sensing**
Jared Tanner, University of Oxford, UK

We consider the problem of solving for the sparsest solution of large underdetermined linear system of equations where the matrix is the adjacency matrix of an expander graph corresponding with at most d neighbours per node. We present a new combinatorial compressed sensing algorithm with provable recovery guarantees, fully parallel with computational runtime less than traditional compressed sensing algorithms, and able to recover sparse signals beyond ℓ_1-regularization. This work is joint with Rodrigo Mendoza-Smith.

16:05–16:40 **Tensor Recovery for Hierarchical Tensors (HT/TT)**
Reinhold Schneider, Technische Universität Berlin, Germany

We will discuss tensor recovery, in particular tensor completion for hierarchical tensors (resp. tree tensor networks) in analogy to matrix completion. Hierarchical Tucker tensor representation, e.g. HT (Hackbusch) and TT (tensor trains, Oseledets & Tyrtyshnikov) are improving the Tucker format to overcome the curse of dimensions. Since they are based only on low rank matrix techniques they offer stable and robust approximation by a low order cost. In particular HSVD (hierarchical SVD) provides a quasi-optimal hierarchical rank $\mathbf{r}$ approximation and these tensors obey a similar manifold structure like rank r matrices. We will discuss new modified Riemannian optimization techniques and/or iterative thresholding algorithms for tensor reconstruction based on the hierarchical SVD (HSVD). Since the hierarchical rank $\mathbf{r} = (r_1, \ldots, r_p)$ is a p-tuple, its minimization is essentially a multi-target optimization problem. Therefore some fundamental issues are still unresolved. Most part of the talk is joint work with H. Rauhut and Z. Stojanac.

Tuesday Plenary Talk

Geometric Clustering via Convex Optimization and Rounding

Rachel Ward

University of Texas at Austin, USA

09:00–10:00

The k-means clustering objective is known to be hard to minimize in general, requiring an exhaustive search over all possible partitions of a given set of data into k clusters. At the same time, fast alternating minimization algorithms act as effective surrogates for the k-means optimization problem in practice, despite only being guaranteed in general to converge to local minimizers. As a compromise between accuracy and speed, we consider a semidefinite programming relaxation of the k-means optimization problem, followed by rounding if necessary. We present several theoretical clustering guarantees for this approach, and discuss how these results unify and improve on existing clustering guarantees. We conclude by discussing the role of convex optimization in geometric clustering problems more generally.

Tuesday Plenary Talk

Analysis of Compressive Sensing in Radar

Holger Rauhut

RWTH Aachen, Germany

14:00–15:00

The application of compressive sensing methods to radar is particularly promising because the assumption of sparsity can often be easily justified. The measurement process is usually modeled by structured random matrices of various types. Their analysis leads to challenging mathematical problems. I will discuss several instances of radar signal processing tasks including randomly positioned antenna arrays and MIMO radar with random waveforms and present (near-)optimal bounds on the number of measurements ensuring recovery of sparse radar scenes.

Tuesday Invited Talks

Morning Session

10:30–11:05 **Machine Learning and Sparsity**

Klaus-Robert Müller, Technische Universität Berlin, Germany

First, a brief introduction into machine learning (ML) and its usage of sparse methods is given. Then sparsity is discussed in the context of the machine learning concept of generalization. Subsequently, limits of interpretability in sparse models are discussed. Finally, if time permits I will review several recent successful applications of the ML framework to atomistic simulations and quantum chemistry [1,2,3,4,5]. This is joint work with O. Anatole von Lilienfeld, Alexandre Tkachenko, Gregoire Montavon, Katja Hansen, Matthias Rupp, Kieron Burke, John Snyder, Andreas Ziehe, Siamac Fazli, Franziska Biegler, Kristof Schütt, Stefan Chmiela, Felix Brockherde and many others.

[1] Rupp, M., Tkatchenko, A., Muller, K.-R., von Lilienfeld, O.A., Fast and Accurate Modeling of Molecular Energies with Machine Learning, Physical Review Letters, 108, 058301 (2012)

[2] Snyder, J., Rupp, M., Hansen, K., Müller, K.-R., Burke, K., Finding density functionals with machine learning, Physical Review Letters, 108, 253002 (2012)

[3] Hansen, K., Montavon, G., Biegler, F., Fazli, S., Rupp, M., Scheffler, M., Tkatchenko, A., von Lilienfeld, O.A., Müller, K.-R., Assessment and Validation of Machine Learning Methods for Predicting Molecular Atomization Energies, J. Chem. Theory Comput., 9, 3404-3419 (2013)

[4] Montavon, G., Rupp, M., Gobre, V., Vazquez-Mayagoitia, A., Hansen, K., Tkatchenko, A., Müller, K.-R., von Lilienfeld, A., Machine Learning of Molecular Electronic Properties in Chemical Space, New Journal of Physics, 15, 95003 (2013)

[5] Hansen, K., Biegler, F., Ramakrishnan, R., Pronobis, W., von Lilienfeld, O.A., Müller, K.-R., Tkatchenko, A., Interaction Potentials in Molecules and Non-Local Information in Chemical Space, Journal of Physical Chemistry Letters, 6, 2326-2331 (2015)

11:05–11:40 **Dictionary Learning from Incomplete Data**
Karin Schnass, University of Innsbruck, Austria

To learn a dictionary of K atoms from a set of noisy or not exactly sparse training samples up to a given precision ϵ usually about $K \log K\epsilon^{-2}$ signals are necessary. If the training data is coming from sensors, with varying degrees of reliability, the number of perfectly received signals can be quite small and so the learning algorithm needs to be adapted to make use also of these incomplete samples. We will present ongoing work with V. Naumova on using also incomplete data samples for dictionary learning based on a modification of the iterative thresholding and residual means (ITKRM) algorithm.

11:40–12:15 **Projections, Learning, and Sparsity for Efficient Data Processing**
Rémi Gribonval, Centre de Recherche INRIA Rennes - Bretagne Atlantique, France

The talk will discuss recent generalizations of sparse recovery guarantees and compressive sensing to the context of machine learning. Assuming some low-dimensional model on the probability distribution of the data, we will see that in certain scenarios it is indeed possible to (randomly) compress a large data-collection into a reduced representation, of size driven by the complexity of the learning task, while preserving the essential information necessary to process it. Two case studies will be given: compressive clustering, and compressive Gaussian Mixture Model estimation, with an illustration on speaker verification.

Afternoon Session

15:30–17:45 **Poster Session**
The poster session will take place in the atrium of the TU main building (Lichthof).

1. Ayemele Djeujo, Romeo (*Universität Siegen, Germany)*
   Secure Matrix (Key) Generation for Secure Compressive Sensing Based Communication Systems
2. Basaran, Mehmet (*Istanbul Technical University, Turkey)*
   Compressed Sensing Based Approaches for the Design of Energy Efficient Communication Systems
3. Betancur, Leonardo (*Universidad Pontificia Bolivariana, Colombia)*
   Analysis of Scenarios for Compressed Sensing DoA
4. Bockelmann, Carsten (*Universität Bremen, Germany)*
   TBA
5. Cornelius, Rasmus (*RWTH Aachen, Germany)*
   Compressed Sensing for Vector Spherical Harmonic Expansion
6. Eisert, Jens; Kliesch, Martin (*Freie Universität Berlin, Germany)*
   Improving Compressed Sensing with the Diamond Norm
7. Fell, Jonathan (*RWTH Aachen, Germany)*
   l1-minimization of Analysis Coefficients
8. Fitzek, Frank (*Technische Universität Dresden, Germany)*
   TBA
9. Fürsich, Benjamin (*Technische Universität München, Germany)*
   CS Terahertz Imaging for Hardware Spiral Scanning
10. Gan, Lu (*Brunel University, UK)*
    Peeling Decoding of LDPC Codes with Applications in Binary Compressed Sensing
11. Gan, Lu (*Brunel University, UK)*
    Structured Random Matrices for Compressed Sensing with Block-Sparse Corruptions

12. Genzel, Martin (*Technische Universität Berlin, Germany)*

Sparse Proteomics Analysis: Learning Forward Models via Compressed Sensing

13. Herrmann, Carsten (*Technische Universität Dresden, Germany)*

Compressed Sensing Meets Network Coding

14. Heublein, Marion (*Karlsruher Institut für Technologie, Germany)*

Compressive Sensing for Neutrospheric Water Vapor Tomography Using GNSS and InSAR Observations

15. Jung, Hans Christian (*RWTH Aachen, Germany)*

TBA

16. Jung, Peter (*Technische Universität Berlin, Germany)*

Semi-blind Channel Estimation Using DCT Phase Retrieval

17. Kämmerer, Lutz; Potts, Daniel; Volkmer, Toni (*Technische Universität Chemnitz, Germany)*

Sparse High-dimensional FFT Based on Rank-1 Lattice Sampling

18. Katzberg, Fabrice; Mertins, Alfred (*Universität zu Lübeck, Germany)*

Dynamic Compressed-sensing Based Soundfield Measurement

19. Kech, Michael (*Technische Universität München, Germany)*

Explicit Frames for Deterministic Phase Retrieval via PhaseLift

20. Keriven, Nicolas (*INRIA, France)*

Sketching for Large-Scale Learning of Mixture Models

21. Kitic, Srdjan (*INRIA, France)*

Multilevel Acceleration of Physics-driven Acoustic Source Localization

22. Kolleck, Anton (*Technische Universität Berlin, Germany)*

1-Bit Compressed Sensing with ℓ_1-norm Support Vector Machines

23. Kueng, Richard (*Universität zu Köln, Germany)*

The Diamond Norm as a Regularizer for Low Rank Matrix Recovery

24. Lu, Yun; Scheunert, Christian (*Technische Universität Dresden, Germany)*

How to Improve the Signal Support Detection Performance in Sparse Gaussian Settings

25. Ma, Jackie (*Technische Universität Berlin, Germany)*

Stable Reconstructions for the Analysis Formulation of ℓ^p-Minimization Using Redundant Frames

26. Navarro, Andres; Sosa, Anibal (*Universidad Icesi, Colombia)*

Subspace Invariant Approaches for Non-authorized Emitter Identification Based on Evaluation of Signal Information Content

27. Palzer, Lars (*Technische Universität München, Germany)*

Lossy Compression of Random Sparse Sources

28. Perelli, Alessandro (*University of Edinburgh, Scotland, UK)*

Compressive Computed Tomography Image Reconstruction with Denoising Message Passing Algorithms

29. Przelaskowski, Artur (*Warsaw University of Technology, Poland)*

Stroke Diagnosis Based on Semantically Compressed Sensing and Adaptive Recovery

30. Puy, Gilles (*INRIA, France)*

Sensing and Adaptive Recovery

31. Riofrio, Carlos; Steffens, Adrian (*Freie Universität Berlin, Germany)*

Practical Applications of Compressed Sensing in Quantum State Tomography

32. Sandbichler, Michael (*University of Innsbruck, Austria)*

The Need for Speed - Accelerating Analysis Operator Learning

33. Sauer, Tomas (*Universität Passau, Germany)*

Prony's Method in Several Variables

34. Seibert, Matthias; Wörmann Juliane (*Technische Universität München)*

Learning Co-Sparse Analysis Operators with Separable Structures

35. Suess, Daniel (*Albert-Ludwigs-Universität Freiburg, Germany)*

Certifying Linear Optical Circuits via Phaseless Estimation Techniques

36. Tampubolon, Ezra (*Technische Universität München)*

On the Decay - and the Smoothness Behaviour of the Fourier Transform

37. Villar, Soledad (*University of Texas at Austin, USA)*

Fast Certificates for Clustering Optimality Using Convex Programming

Wednesday Plenary Talk

Phase Transitions in Semidefinite Relaxations

Andrea Montanari

Stanford University, USA

09:00–10:00

Statistical inference problems arising within signal processing, data mining, and machine learning naturally give rise to hard combinatorial optimization problems. These problems become intractable when the dimensionality of the data is large, as is often the case for modern datasets. A popular idea is to construct convex relaxations of these combinatorial problems, which can be solved efficiently for large scale datasets.
Semidefinite programming (SDP) relaxations are among the most powerful methods in this family, and are surprisingly well-suited for a broad range of problems where data take the form of matrices or graphs. It has been observed several times that, when the ’statistical noise’ is small enough, SDP relaxations correctly detect the underlying combinatorial structures.
I will present a few asymptotically exact predictions for the ‘detection thresholds’ of SDP relaxations, with applications to synchronization and community detection. [Based on Joint work with Adel Javanmard, Federico Ricci-Tersenghi and Subhabrata Sen]

Wednesday Invited Talks

Morning Session

10:30–11:05 **On Empirical Chaos Processes and Their Application in Blind Deconvolution**
Felix Krahmer, Technische Universität München, Germany

The motivation of this talk is the deconvolution of two unknown vectors w and x, each of which is sparse with respect to a generic (but known) basis. That is, one seeks to recover w and x from their circular convolution $y = w * x$. In this paper, we prove a restricted isometry property for this problem, which then entails convergence guarantees for the non-convex sparse power factorization algorithm via recent work by Lee et al. A key ingredient of our proof are tail bounds for random processes of the form

$$\sup_{X \in \mathscr{X}} \sum_{\ell=1}^{L} |\langle b_\ell, X c_\ell \rangle|^2, \tag{1}$$

where the b_ℓ, c_ℓ are independent complex Gaussian vectors and $\mathscr{X}$ is a set of matrices. Such processes can be interpreted as the empirical process corresponding to a chaos process. We analyze such processes in terms of the Talagrand γ_2 functional. For the blind deconvolution application, our results yield convergence guarantees whenever the sparsity of the signals is less than $cL/\log^6 L$, where L is the dimension and c is an absolute constant. This is joint work with Ali Ahmed and Justin Romberg.

11:05–11:40 **Phase Retrieval with Over and Under-sampling**
Bernhard Bodman, University of Houston, USA

This talk presents algorithms accompanied by explicit error bounds for phase retrieval from noisy magnitudes of frame coefficients when the underlying frame varies in its redundancy. In case of sparse signals, the frame can be chosen to span an appropriately chosen subspace of the full Hilbert space. The error bound is inverse proportional to the signal-to-noise ratio and to the square root of the frame size. Upper and lower bounds on the sample values of trigonometric polynomials are a central technique in our error estimates.

11:40–12:15 **Grassmannian Manifolds and Their Interrelations**

Martin Ehler, University of Vienna, Austria

The Grassmannian (manifold), considered as the set of rank-k orthogonal projectors in d-dimensional Euclidean space, has been thoroughly studied in the harmonic analysis literature. We shall explore their interrelations when k varies. This is joint work with Manuel Graef.

Thursday Plenary Talks

Sub-Nyquist Sampling without Sparsity and Phase Retrieval

Yonina Eldar

Technion - Israel Institute of Technology, Israel

09:00–10:00

In recent years there has been an explosion of work on exploiting sparsity in order to reduce sampling rates in a wide-range of applications. In this talk, we consider several examples in which sub-Nyquist sampling is possible without assuming any structure on the signal being sampled. This is possible by careful design of the measurement scheme, together with nonlinear recovery methods. We then show how these concepts of measurement design and optimization-based recovery can be used to tackle a very different set of problems: phase retrieval from Fourier measurements. We begin by considering sampling a signal when we are interested in recovering its power spectrum. Next, we develop the minimal sampling rates required to achieve minimal distortion when representing an arbitrary signal by quantized samples. We then treat sampling of ultrasound signals where the goal is to create a beamformed image from the given samples. Finally, we propose several new measurement techniques in optical imaging that enable phase retrieval even in 1D problems from Fourier measurements.

Modern Optimization Meets Physics: Recent Progress on the Phase Retrieval Problem

Yuxin Chen

Stanford University, USA

14:00–15:00

In many imaging problems such as X-ray crystallography, detectors can only record the intensity of a diffracted wave as opposed to measuring its phase. This means that we need to solve quadratic equations - this is notoriously NP hard - as opposed to linear ones. The focus of this talk is a class of novel nonconvex algorithms, dubbed Wirtinger flows, which finds the solution to randomized quadratic systems from a number of equations (samples) and flops that are both optimal. At a high level, the algorithm can be interpreted as a sort of stochastic gradient scheme, starting from a guess obtained by means of a spectral method. We demonstrate that the Wirtinger flow reconstruction degrades gracefully as the signal-to-noise ratio decreases. The empirical performance shall be demonstrated on phase retrieval problems, which is at the center of spectacular current research efforts collectively known under the name of coherent diffraction imaging aimed, among other things, at determining the 3D structure of large protein complexes.

Thursday Invited Talks

Morning Session

10:30–11:05 **Multiscale Geometric Methods for Statistical Learning and Dictionaries for Data and Images**
Mauro Maggioni, Duke University, USA

We discuss a family of ideas, algorithms, and results for analyzing various new and classical problems in the analysis of high-dimensional data sets. These methods rely on the idea of performing suitable multiscale geometric decompositions of the data, and exploiting such decompositions to perform a variety of tasks in signal processing and statistical learning. In particular, we discuss the problem of dictionary learning, where one is interested in constructing, given a training set of signals, a set of vectors (dictionary) such that the signals admit a sparse representation in terms of the dictionary vectors. We discuss a multiscale geometric construction of such dictionaries, its computational cost and online versions, and finite sample guarantees on its quality. We then mention generalizations of this construction to other tasks, such as learning an estimator for the probability measure generating the data, again with fast algorithms and finite sample guarantees.

11:05–11:40 **Function Interpolation and Compressed Sensing**
Ben Adcock, Simon Fraser University, Canada

The approximation of smooth, high-dimensional functions from finitely-many pointwise samples is an important problem with a range of applications, including uncertainty quantification, numerical PDEs and scattered data approximation. In the last several years, there has been an increasing focus on applying compressed sensing for this problem; in particular, through the used of weighted l1 minimization techniques. In this talk, I will first present a new setup for this problem which seeks to avoid some of the pitfalls of most existing works: namely, the need for a priori estimates on the expansion tail and the resulting loss of interpolation. Next I will present a series of recovery guarantees for weighted l1 minimization. These convey three key benefits. First, unlike some previous results, they are sharp (up to constants and log factors) for large classes of functions regardless of the choice of weights. Second, they allow one to determine a provably optimal weighting strategy in the case of multivariate polynomial approximations in so-called lower sets, in doing so demonstrating how the curse of dimensionality can be effectively circumvented. Third, they can be used to establish the benefits of weighting strategies where the weights are chosen based on prior support information. This provides a theoretical basis for a number of recent studies which have empirically shown this to be the case.

11:40–12:15 **Quantitative MRI Using Model-based Compressed Sensing**
Mike Davies, University of Edinburgh, UK

We will present an overview of the theory of model based compressed sensing, indicating the three key ingredients: good measurement design, low dimensional signal models and practical reconstruction algorithms. Using these principles the recently proposed technique of Magnetic Resonance Fingerprinting will be examined from a compressed sensing perspective and we will develop a principled compressed sensing framework for fully quantitative MRI.

Afternoon Session

15:30–17:45 **Poster Session**
The poster session will take place on the first floor of the TU math building (MA).

1. Badenska, Agnieszka; Blaszczyk, Lukasz (*Warsaw University of Technology, Poland)*

Compressed Sensing for Quaternion Signals

2. Eisert, Jens (*Freie Universität Berlin, Germany)*

Quantum Tomography Using Compressed Sensing

3. Baumgarten, Daniel (*Technische Universität Ilmenau, Germany)*

TBA

4. Fay, Robin (*Universität Siegen, Germany)*

A Cryptographers View on Compressive Sensing

5. Flinth, Axel (*Technische Universität Berlin, Germany)*

Sparse Recovery of Integer Signals with PROMP

6. Graichen, Uwe (*Technische Universität Ilmenau, Germany)*

Compressed Sensing in EEG Recordings, a Spatial Approach Using SPHARA

7. Hieronymus, Jan (*DLR Institute of Optical Sensor Systems, Germany)*

Towards CS for Terahertz Bodyscanners Using Spatial Light Modulators

8. Keiper, Sandra (*Technische Universität Berlin, Germany)*

Analysis of Sleeve Functions in High Dimensions

9. King, Emily (*Universität Bremen, Germany)*

Geometric and Algebraic Spread in Frames

10. Kümmerle, Christian; Sigl, Juliane (*Technische Universität München, Germany)*

Simultanously Structured Sparse Recovery via a Generalized Iteratively Reweighted Least Squares Algorithm

11. Lavrenko, Anastasia (*Technische Universität Ilmenau, Germany)*

Architectures and Signal Processing for Efficient Measurements: From Theory to Applications

12. Lazzaro, Damiana (*University of Bologna, Italy)*

Efficient Compressed Sensing Based Tomographic Reconstruction Using Nonconvex Total Variation Penalties

13. Mohamed, Mostafa Hosni (*Universität Ulm, Germany)*

Deterministic Compressed Sensing with Complex Reed–Solomon Codes

14. Peter, Thomas (*Universität Osnabrück, Germany)*

A Multivariate Prony Method

15. Rettberg, Till (*Universität Rostock, Germany)*

Sparse Recovery Techniques for Spatial Room Impulse Response Capture

16. Shaw, Thomas; Valley, George (*The Aerospace Corporation, USA)*

Compressive Sensing RF Signals Using Optical Speckle Patterns

17. Sparrer, Susanne (*Universität Ulm, Germany)*

Enhanced OMP for the Recovery of Discrete-Valued Sparse Signals

18. Tillmann, Andreas (*Technische Universität Darmstadt, Germany)*

Dictionary Learning for Phase Retrieval

19. Wieruch, Dennis (*Heinrich-Hertz-Institut, Germany)*

Exploiting the Sparsity of Wireless Channels to Identify Non-adjacent Spectrum Usage of Multiple User

Friday Plenary Talk

Blind Deconvolution Meets Blind Demixing: Convexity and the Internet-of-Things

Thomas Strohmer

University of California, Davis, USA

09:00–10:00

Suppose we are given r sensors, each one sends a function z_i (e.g. a signal or image) to a receiver common to all r sensors. During transmission each z_i gets convolved with a function g_i (the g_i may all differ from each other). The receiver records the function y, given by the sum of all these convolved signals. More precisely,

$$y = \sum_{i=1}^{r} z_i * g_i + w,$$

where w is additive noise. Assume that the receiver does neither know the z_i nor the g_i. When and under which conditions is it possible to recover the individual functions z_i and the g_i from just one received function y?
This challenging problem appears in a variety of applications, such as audio processing, image processing, neuroscience, spectroscopy, and astronomy. It also is expected to play a central role in connection with the future Internet-of-Things. Of course, without further assumptions, this problem is highly underdetermined and not solvable. We will prove that under reasonable and practical assumptions, it is indeed possible to recover the r transmitted signals and the associated channels in a robust, reliable, and efficient manner from just one single received signal by solving a semidefinite program. We will tip our toes into some of the mathematical techniques behind our theory and dicuss numerics as well as applications.

Friday Invited Talks

Morning Session

10:30–11:05 **Iteratively Reweighted ℓ_1 Approaches to Sparse Composite Regularization**
Phil Schniter, Ohio State University, USA

Motivated by the observation that a given signal $\boldsymbol{x}$ admits sparse representations in multiple dictionaries $\boldsymbol{\Psi}_d$ but with varying levels of sparsity across dictionaries, we propose two new algorithms for the reconstruction of (approximately) sparse signals from noisy linear measurements. Our first algorithm, Co-ℓ_1, extends the well-known lasso algorithm from the ℓ_1 regularizer $\|\boldsymbol{\Psi x}\|_1$ to composite regularizers of the form $\sum_d \lambda_d \|\boldsymbol{\Psi}_d \boldsymbol{x}\|_1$ while self-adjusting the regularization weights λ_d. Our second algorithm, Co-IRW-ℓ_1, extends the well-known iteratively reweighted ℓ_1 algorithm to the same family of composite regularizers. We provide several interpretations of both algorithms:

1. majorization-minimization (MM) applied to a non-convex log-sum-type penalty,
2. MM applied to an approximate ℓ_0-type penalty,
3. MM applied to Bayesian MAP inference under a particular hierarchical prior, and
4. variational expectation-maximization (VEM) under a particular prior with deterministic unknown parameters.

A detailed numerical study suggests that our proposed algorithms yield significantly improved recovery SNR when compared to their non-composite ℓ_1 and IRW-ℓ_1 counterparts.

11:05–11:40 **Probably Certifiably Correct k-means Clustering**
Dustin Mixon, AFIT, USA

Recently, Bandeira introduced a new type of algorithm (the so-called probably certifiably correct algorithm) that combines fast solvers with the optimality certificates provided by convex relaxations. This talk introduces such an algorithm for the problem of k-means clustering. First, we observe that a certain semidefinite relaxation of k-means is tight with high probability under a certain distribution of planted clusters. Next, we show how to test the optimality of a proposed k-means solution using the relaxation's dual certificate in quasilinear time. (Joint work with Takayuki Iguchi, Jesse Peterson and Soledad Villar.)

Museum Tours

- **Berlin Wall Museum**. The Wall Museum at Checkpoint Charlie displays a permanent exhibition on the history of the Berlin Wall and on the international fight for human rights, including many objects used by fugitives and their helpers in their escape.
  Address: Friedrichstraße 43 - 45, 10969 Berlin.
  Web page: `http://www.mauermuseum.de/`
- **Berlin Underworld/ Berliner Unterwelten**. Experience the history of Berlin from an unconventional perspective! Since 1999, the Berlin Underworlds Association has been offering regular tours into some of the most important underground structures in the city.
  Address: Brunnenstraße 105, 13355 Berlin.
  Web page: `http://berliner-unterwelten.de/home.1.1.html`

Both groups will meet on **Wednesday at 14:15** in front of the TU Berlin main building. For getting to the **Berlin Wall Museum**, we will use public transportation (train tickets will be provided). The transport to the **Berlin Underworld** will be organized by bus. Those who would like to go to the museums on their own should be there at 15:15 (please see the maps on pages 28-29). After the excursions, the participants will need to get back to their hotels on their own.

Conference Dinner

The conference dinner will take place on **Tuesday at 19:00** at the Telecafé in the **TV Tower/ Fernsehturm**, Panoramastraße 1A, 10178 Berlin. The restaurant is in the middle of the sphere of the TV Tower. The TV Tower is located close to the Alexanderplatz. (see the map on page 29).

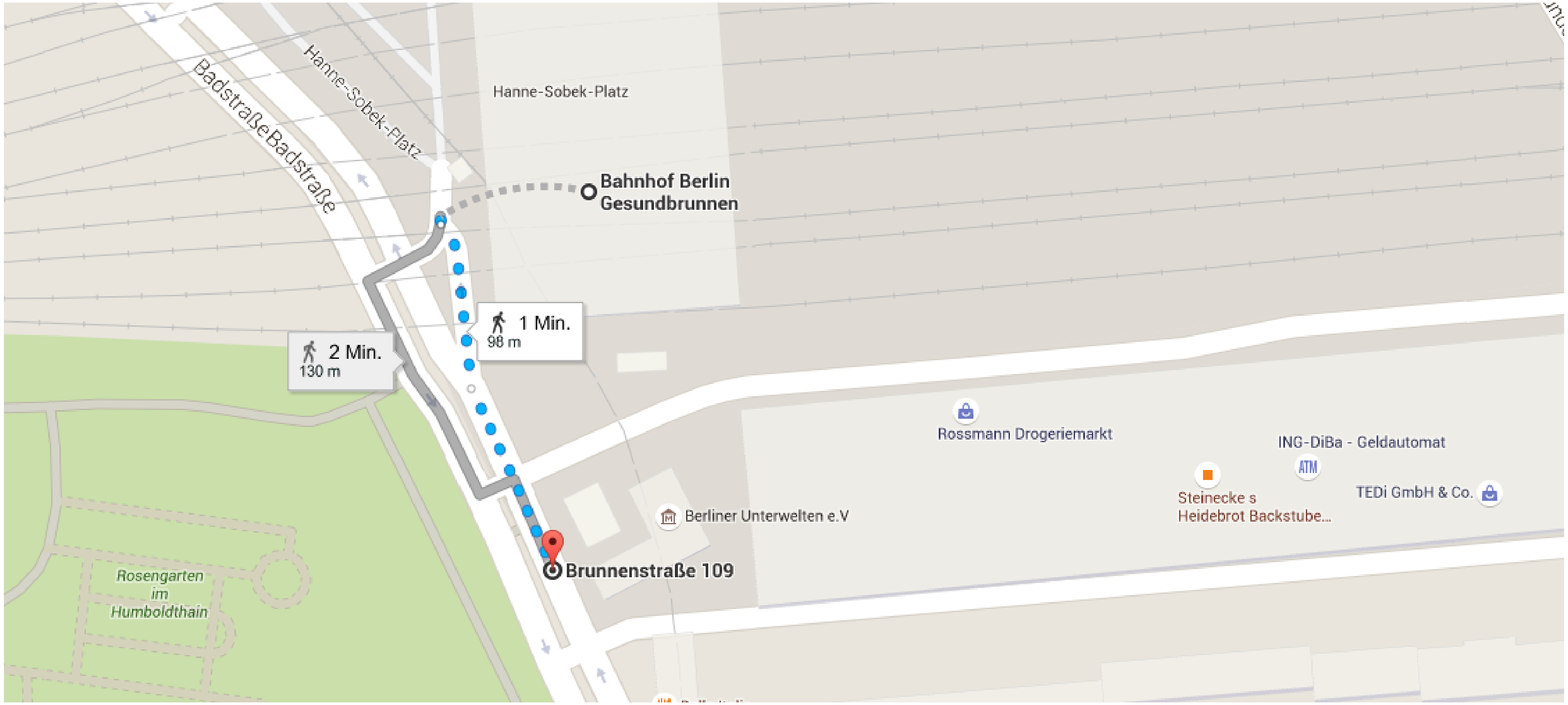
The participants will need to get back to their hotels on their own. Those staying near the university could take the following route: Walk to S Alexanderplatz (line S5/S7/S75) and take one of the S-Bahns going west to S+U Zoologischer Garten or S Savignyplatz.

Getting Around in Berlin

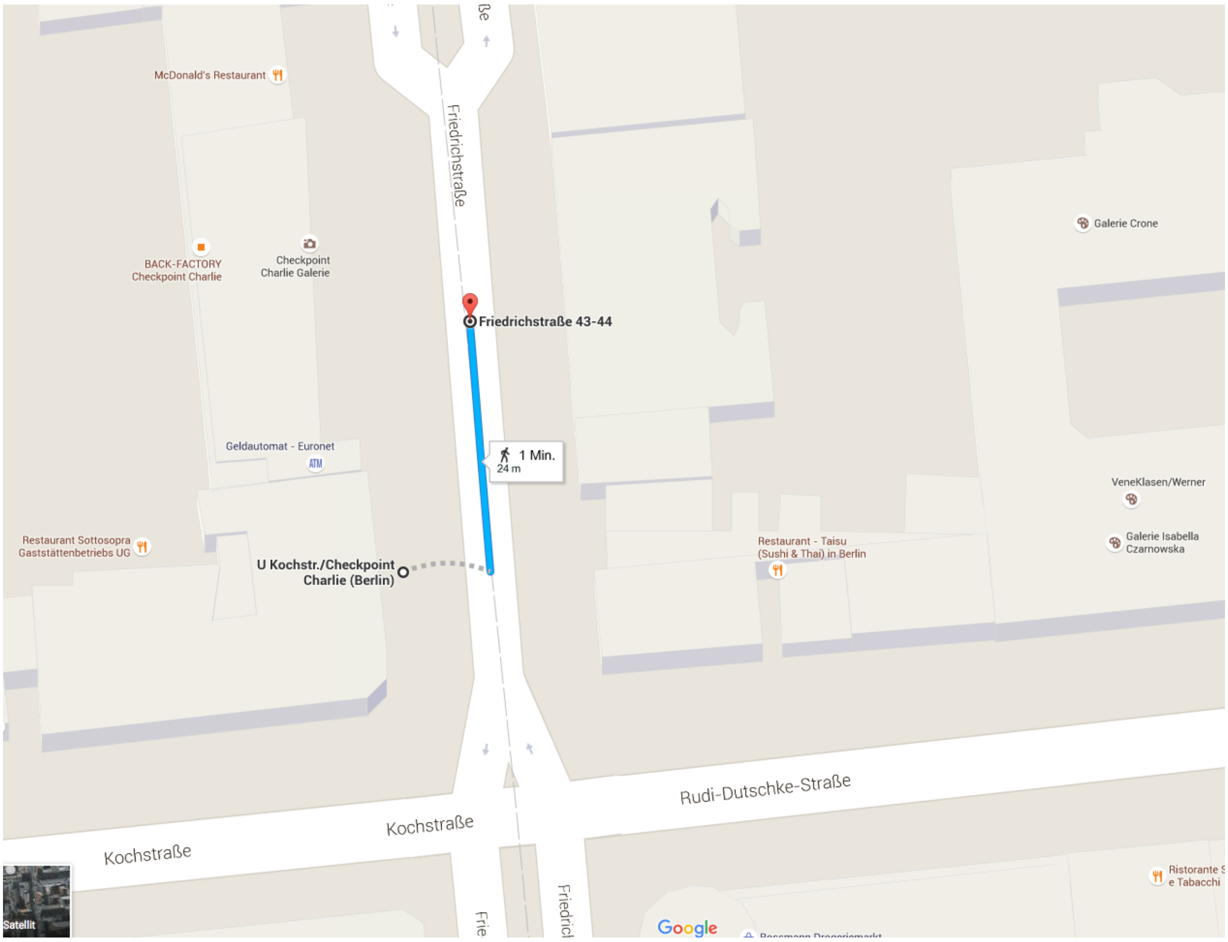
For finding the best routes on public transport, you can use the official web page `www.bvg.de`, or download the Android/iOS application **Fahrinfo Mobile**.

Additional Information

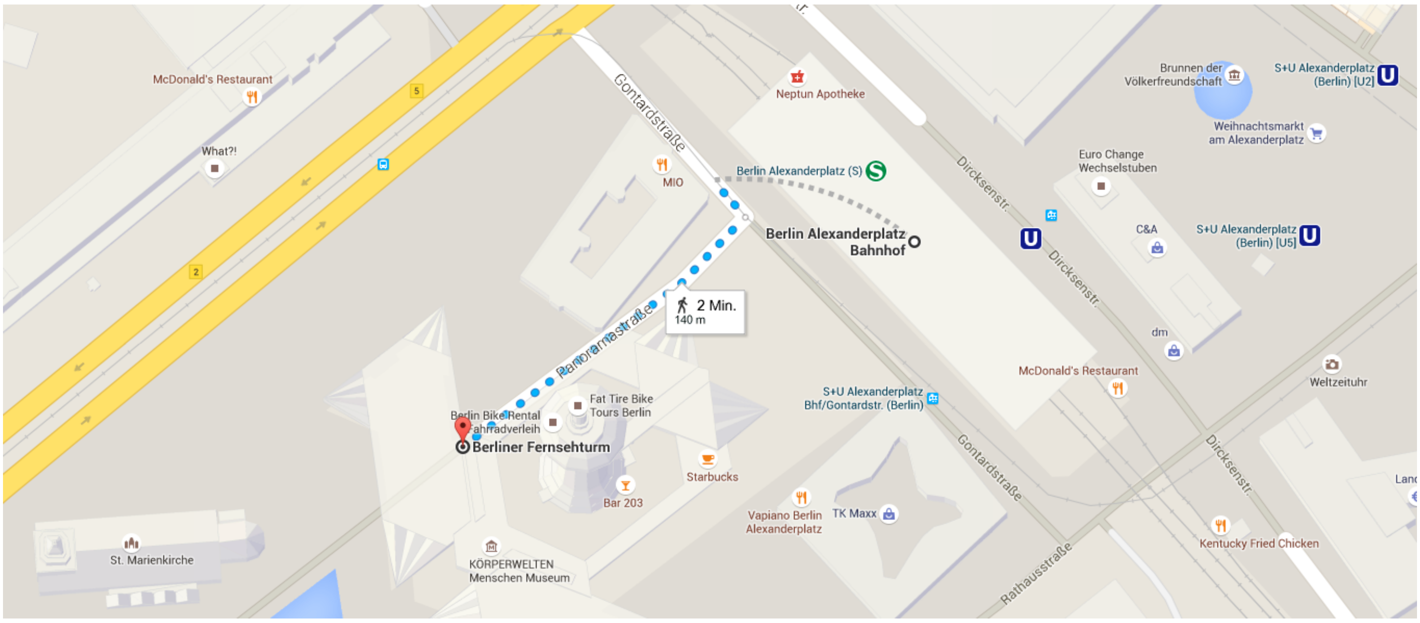
Additional information on sights, exhibitions, events, etc. can be found on the official website of Berlin: `www.berlin.de`.



From S+U Gesundbrunnen to Berliner Unterwelten / Underworld Museum



From U6 Kochstr. / Checkpoint Charlie to Wall Museum



From S+U Alexanderplatz to Conference Dinner

Places to Eat

This is only a selection of places close to the conference venue. See the map overleaf for locations.

Cafeterias / Quick Lunch: Warm dishes, sandwiches, salads, drinks etc, price range for a main dish 2 – 5 €.

Moderately Priced Restaurants: Reasonably priced hot meals, price range for a main dish 5 – 12 €.

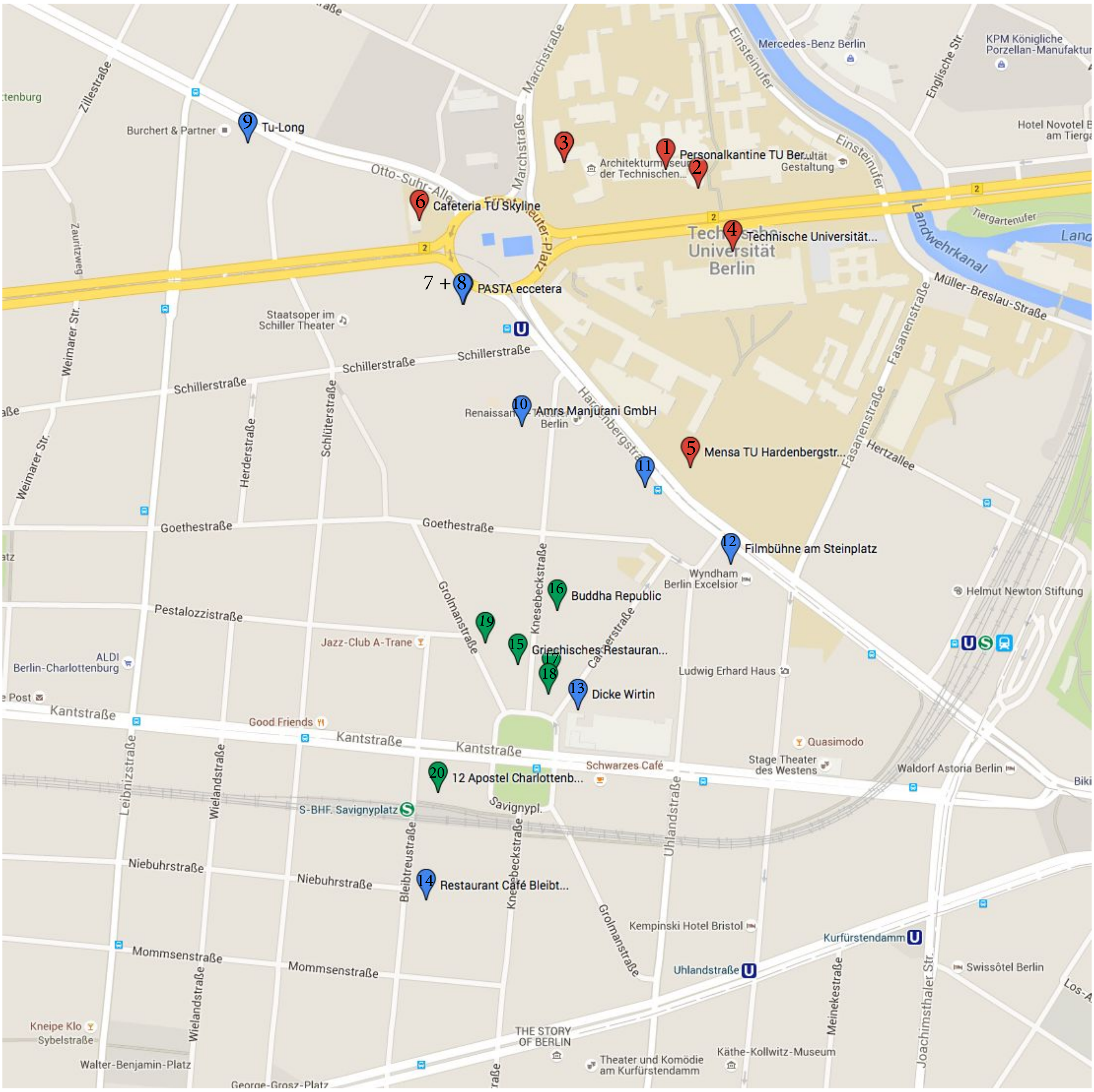
More Expensive Restaurants: More expensive meals, price range for a main dish 10+ € (normally between 10 and 20 €).

Quick Lunch		Moderately Priced	
1	Math Cafeteria - 9th floor	7	Pasta Eccetera
2	Math Cafeteria - ground floor	8	Butenschoen
3	Cafeteria TU Ernst-Reuter-Platz	9	Tu Long (Chinese)
4	Cafeteria TU Hauptgebaeude	10	Manjurani (Indian)
5	TU Mensa Hardenbergstrasse	11	Café Hardenberg
6	Cafeteria TU Skyline	12	Filmbühne am Steinplatz
		13	Dicke Wirtin (Berlin Pub)
		14	Café Bleibtreu

More Expensive	
15	Pratirio (Greek)
16	Buddha Republic (Indian)
17	Aida (Italian)
18	Mar y Sol (Spanish)
19	Florian (German)
20	12 Apostel (Italian)

For menus of the TU Cafeterias, please check the website below

`https://www.tu-berlin.de/menue/service/campus-leben/mensen_cafes/`



9 Tu-Long
Burchert & Partner
3
1 Personalkantine TU Ber...
2
Architekturmuseum der Technischen...
Fakultät Gestaltung
6 Cafeteria TU Skyline
4 Technische Universität...
Technische Universität Berlin
7 + 8 PASTA eccetera
Staatsoper im Schiller Theater
10 Amrs Manjurani GmbH
5 Mensa TU Hardenbergstr...
11
12 Filmbühne am Steinplatz
Wyndham Berlin Excelsior
16 Buddha Republic
19
15 Griechisches Restauran...
17
18
13 Dicke Wirtin
Jazz-Club A-Trane
Good Friends
Ludwig Erhard Haus
Quasimodo
Stage Theater des Westens
Waldorf Astoria Berlin
Schwarzes Café
20 12 Apostel Charlottenb...
S-BHF. Savignyplatz
14 Restaurant Café Bleibt...
Kempinski Hotel Bristol
Kurfürstendamm
Uhlandstraße
Swissôtel Berlin
Helmut Newton Stiftung
Mercedes-Benz Berlin
KPM Königliche Porzellan-Manufaktur
Hotel Novotel Berlin am Tiergarten
Landwehrkanal
Müller-Breslau-Straße
Einsteinufer
Marchstraße
Otto-Suhr-Allee
Ernst-Reuter-Platz
Hardenbergstraße
Fasanenstraße
Hertzallee
Schillerstraße
Goethestraße
Pestalozzistraße
Kantstraße
Niebuhrstraße
Mommsenstraße
Grolmanstraße
Knesebeckstraße
Carmerstraße
Bleibtreustraße
Savignyplatz
Uhlandstraße
Leibnizstraße
Wielandstraße
Schlüterstraße
Herderstraße
Weimarer Str.
Zillestraße
Joachimsthaler Str.
Meinekestraße
Englische Str.
ALDI Berlin-Charlottenburg
Kneipe Klo
Sybelstraße
Walter-Benjamin-Platz
George-Grosz-Platz
THE STORY OF BERLIN
Theater und Komödie am Kurfürstendamm
Käthe-Kollwitz-Museum

berlin

DFG

Alexander von Humboldt
Stiftung/Foundation

ECMath
Einstein Center
for Mathematics Berlin