DFT 2020: The District Fourier Talks

OCTOBER 24TH, 2020 | HOSTED BY AMERICAN UNIVERSITY | WASHINGTON, D.C.

www.american.edu/cas/dft

PROGRAM

$$\frac{1}{N} \sum f_N e^{2\pi i k/N}$$

THE DFT 2020 (*District Fourier Talks*) is the inaugural conference for an annual meeting of local mathematicians, engineers, and applied scientists. This year, the conference will be virtual, with talks/posters presented on line, with virtual break-out sessions. The DFT is for exchanging and exploring recent advances and trends in harmonic analysis and applications. Topics will include signal and image processing, compressed sensing, coding theory, control theory, computational neuroscience, information theory, real and complex analysis, and theoretical, applied, and computational harmonic analysis.

THE DFT 2020 features plenary talks by prominent speakers and special sessions on topics reflecting the current trends in harmonic analysis and engineering applications.

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WELCOME

Interim Dean Max Paul Friedman

Definition: (DFT) The *Discrete Fourier Transform (DFT)* is one of the most widely used tools in science and engineering.

Hello, I'm Max Friedman, Interim Dean of the College of Arts and Sciences at American University. I'd like to welcome you all to the first of what we hope will become annual gatherings of local mathematicians, engineers, and applied scientists. Our conference this year is, of course, virtual, but no less exciting than if we were together in-person. Our conference today is co-organized by American University and Georgetown University, and has input from many of the talented scientists in our region.

Since both institutions are in Washington, we're calling it the "2020 DFT," the "District Fourier Talks." But of course, DFT means something entirely different to mathematicians. What we're really here to talk about and explore today is the bigger-picture, which includes the "DFT," Discrete Fourier Transform, one of the most widely used tools in science and engineering, with applications from new cell phone architectures to new models of human thought studied in neuroscience.

That little twist on the name "DFT" is also used by the University of Maryland, which hosts the "FFT"—the "Fall Fourier Talks."

2020 DFT features plenary talks by prominent speakers, special sessions on topics reflecting the current trends in harmonic analysis and engineering applications, and general sessions. It is a reflection of the rich community we have in the "DMV" for harmonic analysis and its amazing spectrum of related fields.

And so, welcome to American University's Virtual Campus. Talks/posters will be presented online, with virtual break-out sessions. AU and Georgetown dedicated faculty are working to continue a tradition of excellence in both teaching and research embodied in our highest ideal, the Scholar-Teacher. Enjoy this exciting conference.

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CALL FOR TALKS

Acceptance Notice: October 17th

Talk Information/Submission: www.american.edu/cas/dft

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signal and image processing, compressed sensing, coding theory, control theory, computational neuroscience, information theory, real and complex analysis, and theoretical, applied, and computational harmonic analysis.

THE DFT 2020 features plenary talks by prominent speakers and special sessions on topics reflecting the current trends in harmonic analysis and engineering applications.

Plenary Speakers for THE DFT

Name	Affiliation
John Benedetto	University of Maryland
Der-Chen Chang	Georgetown University
Radu Balan	University of Maryland

Special Sessions for THE DFT

Session	Organizer
Sampling and Geometry	S. Casey
Frame Theory	N. Strawn
A "Sampling" of Research at AU	S. Casey

Local Organizing Committee for THE DFT

Name	Affiliation	E-Mail
General E-mail		districtfouriertalks@gmail.com
Stephen Casey	American University	scasey@american.edu
Nate Strawn	Georgetown University	Nate.Strawn@georgetown.edu

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SCHEDULE

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THE DFT 2020 features plenary talks by prominent speakers and special sessions on topics reflecting the current trends in harmonic analysis and engineering applications.

Plenary Speakers for THE DFT

Name	Affiliation	Time/Location
Radu Balan	University of Maryland	9:00-10:00am
John Benedetto	University of Maryland	11:00am-12:00noon
Der-Chen Chang	Georgetown University	2:00-3:00pm

Special Sessions for THE DFT

Session	Organizer	Time/Location
Sampling and Geometry	S. Casey	10:00-11:00 am
Frame Theory	N. Strawn	1:00-2:00 pm
A "Sampling" of Research at AU	S. Casey	3:00-4:00 pm

Local Organizing Committee for THE DFT

Name	Affiliation	E-mail
General		districtfouriertalks@gmail.com
Stephen Casey	American University	scasey@american.edu
Nate Strawn	Georgetown University	Nate.Strawn@georgetown.edu

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PLENARY SPEAKERS

BEURLING MINIMAL EXTRAPOLATION FOR FINITE SETS:
THEORY, EXAMPLES, AND APPLICATIONS

John J. Benedetto

The University Of Maryland

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Abstract

Spectral data will designate the Fourier transform of a complex measure. We motivate the essential role in spectral super-resolution of proving unique extensions to the whole space from given spectral data on finite sets. We pose a total variation minimization problem associated with compressed sensing. Our solution depends essentially on the Beurling theory. The solution introduces a quantitative parameter, whose value gives precise information about the existence of spectral extensions from given spectral data on finite sets. There are many examples, as well as questions to answer. This is a collaboration with Weilin Li.

John J. Benedetto is a harmonic analyst, and founder and Director of the Norbert Wiener Center at the University of Maryland (UMD). He is a Fellow of the AMS and a SIAM Fellow, as well as a Senior Fulbright-Hays Scholar, a SPIE Wavelet Pioneer awardee, and Distinguished Scholar-Teacher of UMD. He is also the adviser of 61 completed PhD students (including 15 proudly co-advised). Benedetto has over 200 publications and has given over 300 colloquia. He is the founding Editor-in-Chief of the J. of Fourier Analysis and Applications and the founding Editor of Springer's Applied and Numerical Harmonic Analysis book series. Finally, he is the fortunate and thankful recipient of many grants through the years.

Heat Kernels for a Class of Degenerate Elliptic Operators

Der-Chen Chang
Georgetown University
chang@georgetown.edu

Abstract

In the first part of this talk, the speaker will discuss heat kernels for a class of degenerate elliptic operators which are closely related to *Grushin operator*:

$$L_G = \frac{1}{2}\big(X_1^2 + X_2^2\big) = \frac{1}{2}\Big(\frac{\partial}{\partial x}\Big)^2 + \frac{1}{2}\Big(x^m \frac{\partial}{\partial y}\Big)^2$$

where $X_1 = \frac{\partial}{\partial x}$ and $X_2 = x^m \frac{\partial}{\partial y}$. It is easy to see this operator is elliptic except when $\{x = 0\}$. We refer to it as the *missing directions*. Given any two points in the Grushin plane, we shall use Hamilton formalism to find all geodesics connecting these two points. Unlike Riemannian geometry, we see that there are points P in the Grushin plane that arbitrarily near P which are connected to P by an infinite number of geodesics. This strange phenomena brings up a new geometry that is so-called *subRiemannian geometry.* Next, we may find a modified complex action function which essentially plays the same role as $d^2(x, y)$ in Riemannian geometry. Finally, we may solve a transport equation to find the volume element to obtain heat kernels. In the second part of this talk, the speaker will also discuss trace asymptotics for the heat kernel of the operator L_G.

Der-Chen Chang received a Bachelor degree from National Tsing Hua University in Taiwan and his Ph.D in Mathematics from Princeton University, Princeton, NJ, in 1987 under the direction of Professor Elias M. Stein. He also received an honorary doctor degree of Science from Fu Jen Catholic University in Taiwan in 2014. In 1988, after a year as a postdoc at MSRI, he moved to the University of Maryland, College Park, where he met Professors John Benedetto and Carlos Berenstein and worked with them closely. His research interests are in harmonic analysis, several complex variables and sub-elliptic PDEs. He moved to Georgetown University in 1998 and is currently a McDevitt Chair in Mathematics and Computer Science and Senior Advisor to the Provost for China Initiatives. He is member of the editorial boards of the Journal of Geometric Analysis, Analysis and Mathematical Physics, Applicable Analysis, Asian-European Journal of Mathematics, and the De-Gruyter Book Series - Advances in Analysis and Geometry.

PERMUTATION INVARIANT REPRESENTATIONS AND
GRAPH DEEP LEARNING
Radu Balan
The University Of Maryland
`rvbalan@math.umd.edu`

Abstract

In this talk two problems seemingly unrelated are discussed: representations of permutation invariant vector sets and optimizations of quadratic assignments. Two matrices of same size are called permutation equivalent if they are equal to one another up to a row permutation. The first problem asks for an Euclidean embedding of the quotient space induced by the row permutation equivalence relation. The approach is inspired by results from commutative algebra theory, measure theory, and reproducing kernel Hilbert space theory. This problem has direct application to graph classification problems where the underlying network has a natural invariance property. The quadratic assignment problem is a NP hard optimization problem.

In this talk the approach is based on graph convolution networks (GCN). A specially designed GCN is shown to produce the optimal solution for a broad class of assignment problems.

Radu Balan received the Bachelor of Engineering degree in Electrical Engineering from the Polytechnic Institute of Bucharest, Romania, in 1992, the Bachelor of Science in Physics from the University of Bucharest, Romania, in 1994, and the Ph.D in Applied Mathematics from Princeton University, Princeton, NJ, in 1998. In 2007, after an 8-year appointment with the Siemens Corporate Research in Princeton, NJ, he moved to the University of Maryland, College Park, where he is a Professor of Applied Mathematics with a joint appointment at the Center for Scientific Computation and Mathematical Modeling. His research interests are in applied harmonic analysis, redundant representations, machine learning and nonlinear analysis. He is currently a member of the editorial board of the Journal of Applied and Computational Harmonic Analysis (ACHA), an Editor of the Journal of Networks and Heterogeneous Media (NHM), and a former Associate Editor of the IEEE Transactions on Information Theory (2017-2020).

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SESSIONS

Sampling and Geometry

ATOMS FOR BERGMAN SPACES ON BOUNDED SYMMETRIC DOMAINS
Jens Christensen
Colgate University
`jchristensen@colgate.edu`

Abstract

We provide new atomic decompositions of Bergman spaces on bounded symmetric domains. These extend results by Coifman and Rochberg from 1980. The usual atoms can be regarded as samples of the Bergman kernel. In this talk we provide a very large new collection of atoms.

SAMPLING EFFECTS ON TOPOLOGICAL FEATURES
Michael Robinson
American University
`michaelr@american.edu`

Abstract

Topological data analysis has become a popular source of features for classification and data exploration. Its flagship tool – persistent homology – is sensitive to a mix of topological and geometric information within the data. Early theoretical results produced sample rate bounds that established how many samples were needed to correctly recover the topology. In practice these bounds are quite loose. Furthermore, both the topology and the geometry of the data play a role in robust classification. Surprisingly few experiments have been performed to assess the impact of sample rates on persistent homology, when used as a source of features. This talk will explore some recent work by the author and his student Robert Green regarding the persistent homology of torus knots under various sample rates.

SAMPLING ON HYPERBOLIC RIEMANN SURFACES
Stephen D. Casey
American University
`scasey@american.edu`

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.

Frame Theory

The Combinatorics of Equiangular Tight Frame Substructures
Emily J. King
Colorado State University
`emily.king@colostate.edu`

Abstract

Given a frame, it is often of interest to ask if a subset of frame vectors also have certain frame properties. The answer to this question has implications for the robustness of the frame representation to erasures and appropriateness of the frame in compressed sensing applications and such subsets sometimes yield optimal subspace configurations. In this talk two combinatorial objects which encode information about equiangular tight frame substructures will be presented: binders and paired difference sets. Connections to matroids, honeycombs, and spectrahedra will also be touched on.

Optimal Parseval frames
Jameson Cahill
University of North Carolina Wilmington
`cahillj@uncw.edu`

Abstract

We introduce three quantities called total coherence, total volume, and nuclear energy, and we show that equiangular Parseval frames maximize all three of these quantities over the set of all Parseval frames. We then show that equiangular Parseval frames also maximize the total volume and nuclear energy over the set of equal norm frames. Along the way we derive a bound on the smallest k-dimensional volume in an equal norm frame which is a generalization of the Welch bound.

Multiscale metrics for weakly-supervised learning
James M. Murphy
Tufts University
`jm.murphy@tufts.edu`

Abstract

Methods for unsupervised and semisupervised learning on large, sparsely connected net- works are developed. We propose metrics and related sampling schemes that exploit multi- scale structure in the networks to provably capture latent cluster hierarchies. These methods enjoy robust theoretical guarantees and fast numerical schemes that scale. Applications to high-dimensional image processing and prediction in incomplete and noisy protein-protein interaction networks are emphasized.

Data Imputation from Total Variation Minimization
Nate Strawn
Georgetown University
`Nate.Strawn@georgetown.edu`

Abstract

Isometrically embedding data into "nice" function spaces over graphs allows us to generalize Total Variation Minimization from image processing to Data Imputation in data processing. This talk explores theory and algorithms for this approach.

Visual Illusions Related to Harmonic Analysis
Arthur G. Shapiro
American University
`arthur.shapiro@american.edu`

Abstract

Harmonic analysis is crucial for understanding how the brain turns a visual image into visual perception. The brain uses a process analogous to Fourier analysis to decompose the visual image into the frequency domain. The question I will address concerns how the brain is able to select the appropriate frequency range even though our eyes are constantly moving. To illustrate the answers to this problem, I will present a number of visual illusions created in my laboratory that arise when information at different frequency ranges are juxtaposed relative to each other. The results highlight the brain's strategies for making sense of a complex environment.

Change-point detection in the correlation structure of time series
Michael Baron
American University
`baron@american.edu`

Abstract

Prompt detection of changes not only in the mean, but also in the second moments of a time series may convey important information. Appearance of a correlation distinguishes unrelated spontaneous events from a pattern that may imply a spread of infection or a spread of violence. We propose a solution to this change-point detection problem in frequency domain, focusing on changes in the spectral distribution of a stationary process and using asymptotic distribution results for periodograms. Changes in spectra have their own scope of applications, from electroencephalography to marine meteorology.

Stable distributions and Green's functions for fractional diffusions

John Nolan
American University
jpnolan@american.edu

Abstract

Stable distributions are a class of distributions that have important uses in probability theory. They also have a applications in the theory of fractional diffusions: symmetric stable density functions are the Green's functions of the fractional heat equation. We describe efficient numerical representations for these Green's functions, enabling their use in numerical solutions of fractional heat equations.

Independent Vector Analysis using a Riemannian Averaged Fixed-Point Algorithm for MGGD Parameter Estimation

Zois Boukouvalas
American University
boukouva@american.edu

Abstract

Due to its simple parametric form, multivariate Gaussian distribution (MGGD) has been widely used in modeling vector-valued signals. Therefore, estimation of its parameters is of significant interest for a number of applications. Independent vector analysis (IVA), is a recent generalization of independent component analysis (ICA), that enables the joint analysis of datasets and extraction of latent sources through the use of a simple yet effective generative model. MGGD provides an effective way to model the latent multivariate variables–sources–and the performance of the IVA algorithm highly depends on the estimation of the source parameters. In this talk, we present an estimation technique based on a fixed point algorithm implemented on the space of symmetric positive definite matrices and demonstrate its successful application to IVA. We quantify the performance of MGGD parameter estimation using the new algorithm and further verify the effectiveness of the new IVA algorithm using simulated data.