Joint Alberta – BC Seminar: Program and Abstracts

Program

Tuesday, August 7

9:00 am	*Convergence Analysis of Multigrid Methods: An Approach via Approximation Theory* **Rong-Qing Jia**, University of Alberta
9:45 am	*Symplectic Numerical Schemes for Stochastic Hamiltonian Equations* **Jian Deng**, University of Alberta
10:15 am	**Coffee Break**
11:00 am	*Asymptotic analysis for viscoelastic oldroyd fluid* **Kun Wang**, University Alberta
11:30 am	*Multi-scale asymptotic analysis and computation of coupled thermo-elasticity system* **Xin Wang**, University of Alberta
12:00 pm	**Lunch**

Wednesday, August 8

9:00 am	*Blind source separation and background suppression in audio* **Yang Wang**, Michigan State University
9:45 am	*Poisson kernel, Gabor frames, and Balayage of Fourier transform* **Enrico Au-Yeung**, University of British Columbia
10:30 am	**Coffee Break**
11:15 am	*High accuracy finite frame quantization using Sigma-Delta schemes* **Rayan Saab**, Duke University
12:00 pm	**Lunch**

Thursday, August 9

9:00 am	*Fast Framelet/wavelet Transform and its Properties* **Bin Han**, University of Alberta
9:45 am	*Dual-tree Complex Wavelet Transform and The Directional Framelet and Their Applications* **Zhenpeng Zhao**, University of Alberta
10:15 am	**Coffee Break**
11:00 am	*Breakdown of Smoothness Equivalence in Nonlinear Subdivision Schemes* **Tom Duchamps**, University of Washington
11:30 am	*Local Interpolation with Optimal Polynomial Exactness in Refinement Spaces* **Mpafareleni Rejoyce Gavhi**, University of Alberta
12:00 pm	**Lunch**

Friday, August 10

9:00 am	*Beyond ℓ_1-norm minimization for sparse signal recovery* **Hassan Mansour**, University of British Columbia
9:45 am	*Analysis of the Analysis Model for ℓ_1 Inpainting* **Xiaosheng Zhuang**, University of Alberta
10:15 am	**Coffee Break**
11:00 am	*Non-convex compressed sensing using partial support information* **Navid Ghadermarzy**, University of British Columbia
11:30 am	*Compressive Imaging by Generalized Total Variation Minimization* **Jie Yan**, University of Victoria
12:00 pm	**Lunch**

Abstracts (in alphabetic order by speaker lastname)

Speaker: **Enrico Au-Yeung** (University of British Columbia)

Title: *Poisson kernel, Gabor frames, and Balayage of Fourier transform*

Abstract: Consider the following two problems; one about Gabor frames and the other about translates of the Poisson kernel. (1) Find a sufficient condition for a sequence of points in the time-frequency domain so that these points generate a Gabor frame in $L^2(\mathbb{R})$. (2) Let $P(t) = 1/(1+t^2)$ be the Poisson kernel. Find a necessary and sufficient condition for a sequence of points $x[n]$, so that the sequence of functions obtained by the translates of the Poisson kernel, namely $f_n(t) = P(t - x[n])$, spans the space $L^1(\mathbb{R})$. In this talk, we provide a unified treatment to these type of problems using the theory of Balayage, which was initially developed by Beurling, in the setting of Fourier frames.

Speaker: **Jian Deng** (University of Alberta)

Title: *Symplectic Numerical Schemes for Stochastic Hamiltonian Equations*

Abstract: We propose a new method to develop high order symplectic schemes for Hamiltonian stochastic differential equations. This approach is an non- trivial extension to the stochastic case of the methods based on generating functions for deterministic Hamiltonian systems. We consider the stochastic differential equations in the sense of Stratanovich:

$$\begin{aligned} dP &= -\frac{\partial H^{(0)}(t,P,Q)}{\partial Q}dt - \sum_{r=1}^{m} \frac{\partial H^{(r)}(t,P,Q)}{\partial Q} \circ dw_t^r, \quad P(t_0) = p \\ dQ &= \frac{\partial H^{(0)}(t,P,Q)}{\partial P}dt + \sum_{r=1}^{m} \frac{\partial H^{(r)}(t,P,Q)}{\partial P} \circ dw_t^r, \quad Q(t_0) = q \end{aligned} \tag{1}$$

where P, Q, p, q are n-dimensional vectors with the components $P^i, Q^i, p^i, q^i, i = 1, \ldots, n$, and $w_t^r, r = 1, \ldots, n$ are independent standard Wiener Processes. The equations (1) represent a stochastic Hamiltonian system for which the stochastic flow $(p, q) \to (P, Q)$ is symplectic. We use the relationship between the generating function and the solutions of the stochastic Hamiltonian system to construct symplectic numerical schemes based on approximations of the solutions of the partial differential equation. By construction these schemes preserve the symplectic structure. We illustrate the excellent long term accuracy of the proposed schemes on several examples with additive and multiplicative noise.

Speaker: **Tom Duchamp** (University of Washington)

Title: *Breakdown of Smoothness Equivalence in Nonlinear Subdivision Schemes*

Abstract: A nonlinear subdivision scheme is said to satisfy "smoothness equivalence" if it has the same smoothness properties as the underlying linear scheme. Work by Wallner-Dyn, Xie-Yu, and Grohs give certain "proximity conditions" that imply smoothness equivalence. In this talk, I'll present examples built from C^k linear subdivision schemes where the nonlinear subdivision scheme fails to be C^k. This is joint work with Gang Xie and Thomas Yu.

Speaker: **Mpafareleni Rejoyce Gavhi** (University of Alberta)

Title: *Local Interpolation with Optimal Polynomial Exactness in Refinement Spaces*

Abstract: We show how the solution of a certain polynomial identity, based on the values at the integers of a given refinable function, yields an explicit construction method for a local interpolation operator into the linear space generated by the integer shifts of this refinable function, with, moreover, optimal polynomial exactness, as determined by the order of the sum rule-condition satisfied by the corresponding refinement sequence. Such an approximation operator could prove useful, for example, in the first step of a wavelet decomposition algorithm based on the refinable function, where the given signal is to be mapped into a refinement space of sufficiently high resolution level.

In addition, we demonstrate how the solution of a second polynomial identity, belonging to the same general class as the one above, may be applied to obtain a refinable function with prescribed values at the integers, and thereby making it possible in principle for the first polynomial identity above to be solved in a straightforward manner. Finally, we consider the particular example where the refinable function attains normalized binomial coefficient values at the integers.

Speaker: **Navid Ghadermarzy** (University of British Columbia)

Title: *Non-convex compressed sensing using partial support information*

Abstract: In this talk, we will address the recovery conditions of weighted ℓ_p minimization for signal reconstruction from compressed sensing measurements when (possibly inaccurate) partial support information is available. First we will motivate the use of (weighted) ℓ_p minimization with $p < 1$ and point out its advantages over weighted ℓ_1 minimization when there is prior information on the support of the signal that is possibly partial and inaccurate. Then we will provide theoretical guarantees of sufficient recovery conditions for weighted ℓ_p minimization, which are better than those for (unweighted) ℓ_p minimization as well as those for weighted ℓ_1. In the last part of the talk, we will illustrate our results with some numerical experiments stylized applications.

Speaker: **Bin Han** (University of Alberta)

Title: *Fast Framelet/wavelet Transform and its Properties*

Abstract: The theory of classical wavelets and framelets is often extensively studied in the function setting, in particular, the function space L_2; the discrete wavelet (or framelet) transform is often regarded as a byproduct of the multiresolution analysis, that is, decomposition and reconstruction of functions in L_2 via the nested subspaces of L_2. However, to understand the advantages and disadvantages of wavelets and framelets, it is more natural and important to directly study the fast framelet/wavelet transform and its properties. In this talk, we shall present a comprehensive study of framelets and wavelets using an algorithmic approach. We shall talk about the discrete framelet transform and its three fundamental properties: perfect reconstruction, sparsity, and stability. Then we shall talk about systems of framelets and wavelets in the discrete setting. We shall also make the connection between framelets and wavelets in the discrete setting to the classical theory of wavelets and framelets. We shall see that framelets and wavelets can be fully understood without any use of multiresolution analysis and the function space L_2.

Speaker: **Rong-Qing Jia** (University of Alberta)

Title: *Convergence Analysis of Multigrid Methods: An Approach via Approximation Theory*

Abstract: In this talk we use approximation theory to establish a very general theory for convergence of multigrid methods. Our convergence analysis is valid for both algebraic and geometric multigrid methods and for almost all smoothing operators. In contrast to the existent theory, our convergence analysis works for elliptic equations of any (even) order without additional requirement of regularity of the solution. In addition to the finite element method, we demonstrate applicability of our convergence analysis to the finite difference method.

Speaker: **Hassan Mansour** (University of British Columbia)

Title: *Beyond ℓ_1-norm minimization for sparse signal recovery*

Abstract: Sparse signal recovery has been dominated by the basis pursuit denoise (BPDN) problem formulation for over a decade. In this paper, we propose an algorithm that outperforms BPDN in finding sparse solutions to underdetermined linear systems of equations at no additional computational cost. Our algorithm, called WSPGL1, is a modification of the spectral projected gradient for ℓ_1 minimization (SPGL1) algorithm in which the sequence of LASSO subproblems are replaced by a sequence of weighted LASSO subproblems with constant weights applied to a support estimate. The support estimate is derived from the data and is updated at every iteration. The algorithm also modifies the Pareto curve at every iteration to reflect the new weighted ℓ_1 minimization problem that is being solved. We demonstrate through extensive simulations that the sparse recovery performance of our algorithm is superior to that of ℓ_1 minimization and approaches the recovery performance of iterative re-weighted ℓ_1 (IRWL1) minimization of Candès, Wakin, and Boyd, although it does not match it in general. Moreover, our algorithm has the computational cost of a single BPDN problem.

Speaker: **Rayan Saab** (Duke University)

Title: *High accuracy finite frame quantization using Sigma-Delta schemes*

Abstract: In this talk, we address the digitization of oversampled signals in the finite-dimensional setting. In particular, we show that by quantizing the N-dimensional frame coefficients of signals in $\mathbb{R}^d$ using Sigma-Delta quantization schemes, it is possible to achieve root- exponential accuracy in the oversampling rate $\lambda := N/d$ (even when one bit per measurement is used). These are currently the best known error rates in this context. To that end, we construct a family of finite frames tailored specifically for Sigma-Delta quantization. Our construction allows for error guarantees that behave as $e^{-c\sqrt{\lambda}}$, where under a mild restriction on the oversampling rate, the constants are absolute. Moreover, we show that harmonic frames can be used to achieve the same guarantees, but with the constants now depending on d. Finally, we show a somewhat surprising result whereby random frames achieve similar, albeit slightly weaker guarantees (with high probability). Finally, we discuss connections to quantization of compressed sensing measurements. This is joint work in parts with F. Krahmer, R. Ward, and O. Yilmaz.

Speaker: **Kun Wang** (University of Alberta)

Title: *Asymptotic analysis for viscoelastic oldroyd fluid*

Abstract: In this talk, the asymptotic analysis of the two-dimensional viscoelastic Oldroyd flows is presented. With the physical constant ρ/δ approaching zero, where ρ is the viscoelastic coefficient and $1/\delta$ the relaxation time, the equations of the viscoelastic Oldroyd fluid motion converge to the viscous model known as the Navier-Stokes equations. Both the continuous and discrete uniform-in-time asymptotic errors are provided. The theoretical predictions are confirmed by numerical simulations. Finally, we will discuss topics which are currently being investigated.

Speaker: **Xin Wang** (University of Alberta)

Title: *Multi-scale asymptotic analysis and computation of coupled thermo-elasticity system*

Abstract: In the study of composite materials, the coupled system of PDEs for linear thermo-elasticity incorporates the effect of strain and temperature. Solving the system for periodic composite materials is a large-scale scientific computing problem. In this talk, a multi-scale asymptotic analysis of the coupled thermo-elasticity system is presented. In this approach, we first apply Laplace transformation with respect to the time variable, a novel multi-scale FEM algorithm is then used for solving the resulting system. The proposed method is highly suitable for parallel computation. We will report some 3-D numerical simulations and discuss the difficulties in the theoretical study.

Speaker: **Yang Wang** (Michigan State University)

Title: *Blind source separation and background suppression in audio*

Abstract: An important problem in signal processing is the "cocktail party problem", where several people are speaking at the same time and the objective is to separate the speeches from different speakers, typically using several microphones placed in different localities. This process is known as Blind Source Separation (BSS). Numerous techniques had been proposed to solve the cocktail party problem, with various degrees of success. Many of these techniques work very well for artificially mixed speech signals, but when it comes to real recordings, even with two speakers, the success is rather mixed. In this talk, I will present an overview of the techniques for BSS, and present a very robust method for solving the cocktail party problem in real recordings with two speakers based on time-frequency separation.

A related problem is to suppress background noise so the intended speaker can be heard more clearly. We present an effective technique for solving this problem and discuss potential improvements for future study.

Speaker: **Jie Yan** (University of Victoria)

Title: *Compressive Imaging by Generalized Total Variation Minimization*

Abstract: Total variation (TV) has for the last two decades proven effective in solving several key image processing problems. Encouraged by performance enhancement obtained using ℓ_p-minimization (with $p < 1$) relative to that of ℓ_1-minimization in standard compressive sensing, we present an algorithm for the reconstruction of digital images from undersampled measurements, where the concept of conventional TV is extended to a generalized TV (GTV) that involves pth

power (with $p < 1$) of the discretized gradient of the image. To deal with the nonconvex issue arising from this new formulation, weighted TV (WTV) is introduced and an iterative reweighting technique is applied so that each iteration of the algorithm is carried out in a convex setting. In addition, the Split Bregman method is reformulated in a major way so as to solve the WTV minimization problem involved. We include a numerical example, where a digital image is reconstructed by a limited number of measurements in a compressive sensing framework, to demonstrate significant performance gain by the proposed GTV minimization method relative to that achieved by the conventional TV-minimization based method.

Speaker: **Zhenpeng Zhao** (University of Alberta)

Title: *Dual-tree Complex Wavelet Transform and The Directional Framelet and Their Applications*

Abstract: In this talk, we discuss the construction of dual-tree complex wavelet transform and the directional framelet. By considering two parallel trees of wavelet decomposition properly , we have the more directional, shift-invariance dual-tree complex wavelet. Based on the Meyer wavelet, and separating the positive and negative high-frequency bands, we use a redundant wavelet decomposition system, and get the directional framelet transform. Their applications in 1-d and 2-d signal denoising are also discussed.

Speaker: **Xiaosheng Zhuang** (University of Alberta)

Title: *Analysis of the Analysis Model for ℓ_1 Inpainting*

Abstract: In this talk, we shall focus on sparse approximation using directional multiscale representation systems and mathematical imaging using ℓ_1 minimization techniques. We shall discuss about an abstract model for data recovery problems such as image inpainting. By placing the ℓ_1 minimization on the analysis side, we analyze the inpainting recovery result and show that the recovery error can be controlled by two important quantities: the cluster coherence and the relative sparsity. As an application of the abstract setting, we propose a specific model for seismic inpainting and give a theoretical analysis of recovery results for Meyer wavelets and shearlets using ℓ_1 minimization. We provide a quantitative result for comparison between wavelet inpainting and shearlet inpainting.