Annual Report on
CRG in Applied and Computational Harmonic Analysis

This PIMS CRG in applied and computational harmonic analysis has just started this year. The main goal of our CRG this year is to bring all CRG members together to become familiar with each other's research work and then to establish possible connections between CRG members for future collaboration. Here is a short summary of all CRG activities:

1. Two major CRG events: an international conference and an afterwards summer school.
2. Two PIMS CRG PDFs have been recruited (one at UBC and the other at UA).
3. List of PIMS visitors in 2011.
4. Collaborations and research activities of CRG members.
5. Some publications in 2011 (but most if not all are supported by sources other than PIMS. Since our CRG just started, publications directly related to PIMS CRG are almost impossible)

1. Major Specific Events of CRG in 2011:

Event 1: International Conference on Applied Harmonic Analysis and Multiscale Computing, July 25--28, 2011, at the University of Alberta, Edmonton, Canada.

This conference has 112 participants from 12 countries, and there are 65 oral presentations: 6 1-hour plenary talks (including Steve Smale--fields medalist with numerous awards, and Gibert Strang-a renowned American mathematician with numerous awards) , 36 40-minute talks (including many world first class researchers in the area of applied and computational harmonic analysis), 5 20-minute invited talks, and 18 20-minute contributed talks (including many promising and active young researchers in this area). With PIMS's major generous support of this conference and its afterwards school, due to the effort of our CRG member Prof. Yau Shu Wong, we also received generous auxiliary financial support from many sources for this conference and its afterwards summer school; these additional sponsors include MITACS, Alberta Innovates-Technology Futures, Grant Mac Ewan University, JackTek System Ltd., Citizen Travel Ltd, last but not least, the University of Alberta including China Institute, Faculty of Sciences, Department of Mathematical and Statistical Sciences, and Applied Mathematics Institute.

This international conference concentrates on recent advances on applied and computational harmonic analysis, multiscale-based methods, and their various applications in the broad sense. The topics of interest include, but not limited to,

Applied harmonic analysis
Approximation theory
Compressive sampling and sparsity
Computational methods
Image and signal processing
Learning theory and algorithms
Multiscale-related numerical algorithms
Sampling theorems in signal processing
Subdivision schemes
Wavelets and framelets

Scientific Committee:
Carl de Boor (University of Wisconsin - Madison)
Ronald DeVore (Texas A&M University)
Thomas J. R. Hughes (The University of Texas at Austin)
Stanley Osher (University of California at Los Angeles)
Gilbert Strang (Massachusetts Institute of Technology)

Organizers:
Elena Braverman (University of Calgary)
Bin Han (University of Alberta)
Rong-Qing Jia (University of Alberta)
Yau Shu Wong (University of Alberta)
Ozgur Yilmaz (University of British Columbia)

Participating CRG members:
Michael Adams (University of Victoria)
Elena Braverman (University of Calgary)
Tom Duchamp (University of Washington)
Bin Han (University of Alberta)
Rong-Qing Jia (University of Alberta)
Peter D. Minev (University of Alberta)
Bernard Shizgal (University of British Columbia)
Yau Shu Wong (University of Alberta)
Ozgur Yilmaz (University of British Columbia)

Student participants associated with CRG members:
Menglu Che (University of Alberta)

Brock Hargreaves (University of Calgary)
Jian Deng (University of Alberta)
Md Kamrujjaman (University of Calgary)
Hassan Mansour (University of British Columbia)
Rayan Saab (Duke University)
Wei Zhao (McMaster University)
Zhenpeng Zhao (University of Alberta)
Xiaosheng Zhuang (University of Osnabrueck)

This conference has two major purposes. One of the goals is to bring all CRG members and their associated students together so that they can talk to each other in person, listen to each other's talks, and to establish connections to foster possible collaborations for future years. We have 9 CRG members attending this conference and 6 of them have presented 40-minute talks in the conference. We have total 9 associated CRG students attending the conference and 6 of them have presented 20-minute talks. Another goal is to bring worldwide leading experts and first class researchers in the area of applied and computational harmonic analysis to our conference so that all CRG members have the opportunities to talk and discuss with these experts. In fact, many of the invited speakers in this conference already have research connections with our CRG members. This conference provides another opportunity for our CRG members to collaborate or to establish collaborations with worldwide leading experts in the area of applied and computational harmonic analysis. The participations of graduate students and postdoctoral fellows associated with our CRG members also helps our students to interact actively with experts in this area and learn the current developments in this area. Also, this conference and its afterward summer school also enable us to attract the research group on machine learning at the Department of Computing Sciences, and group on signal processing at the Department of Physics in the University of Alberta. In fact, several faculty members such as Professors Russell Greiner, Dale Schuurmans, and Sharmin Nilufar as well as several graduate students in these two departments have presented talks in our conference. Many students from these departments also attended the afterwards summer school. The conference makes it possible for our CRG members to explores some potential collaborations beyond the Department of Mathematics.

Event 2: Summer School on Applied and Computational Harmonic Analysis, July 29-31, 2011, at the University of Alberta, Edmonton, Canada.

This summer school has 51 participants, and 4 tutorial lecturers have presented 2.5 days tutorial lectures on several directions of applied and computational harmonic analysis. Professor Steve Smale presented a nice introduction to the theory of learning. Professor Ding-

Xuan Zhou presents tutorial lectures on the current-state-of-art research in the area of learning theory. Professor Zuowei Shen gave tutorial talks on both the theory of wavelet analysis, and its applications to image processing. The summer school is completed by two tutorial lectures by Bin Han on the algorithmic aspects of wavelets and framelets.

Though this is a very short and fast paced summer school for students, the purpose of the summer school is to bring the attention of students to several directions in the area of applied and computational harmonic analysis. The short summer school is compensated by the fact that all the lecture notes are posted online so that interested students can get all the necessary information to pursue further research in the area of his/her interest.

2. PIMS PDFs and New Students:

New CRG PIMS PDFs: Two PIMS CRG PDFs have been recruited in 2011.
Dr. Enrico Au-Yeung, at the University of British Columbia, hosted by Ozgur Yilmaz.
Dr. Kun Wang at the University of Alberta, hosted by Rong-Qing Jia and Yau Shu Wong.

Dr. Au-Yeung joined UBC as a PIMS PDF in September 2011. He received his PhD in Mathematics at the University of Maryland, College Park under the supervision of John J. Benedetto. During his PhD he worked on various problems in harmonic analysis and extended frame theory by bringing together the Wiener-Beurling theory of spectral synthesis and the notion of balayage. As a result he constructed semi-discrete Gabor frames, which give rise to new non-uniform sampling formulas. At University of British Columbia, Dr. Au-Yeung will work, under the supervision of Ozgur Yilmaz, on several problems in the general area of sparse approximations and compressed sensing. Currently he is working on a project where he is using his expertise in non-uniform sampling theory to tackle some important problems in sparse approximations and compressed sensing. He has already started interacting with a large group of researchers (including other faculty, postdoctoral fellows, and graduate students) who make up a very active research group in this area.

Dr. Kun Wang is a promising young mathematician and will start his PDF award in January 2012. Working with Rong-Qing Jia and Yau Shu Wong, he plans to applied harmonic analysis to develop efficient numerical algorithms for partial differential equations such as Navier-Stokes equation, and the proposed methods will be demonstrated to practical applications for problems in sciences and engineering such as fluid mechanics.

New coming graduate students in 2011:
Menglu Che, MSc student, supervised by Bin Han
Li Zhang, PhD student, co-supervised by Peter Minev and Bin Han

Other graduate students and PDFs:
Jian Deng, PhD student, University of Alberta
Md. Kamrujjaman, PhD student, University of Calgary
Johnwill Keating, PhD student, University of Alberta
Ping Li, MASc, University of Victoria
Srinath Madhavan, Research engineer at Good Year R&D Centre, Acron.
Andriy Roshchenko, PhD student, University of Alberta
Reinel Sospedra-Alfonso, Postdoctoral fellow, University of British Columbia
Xi Tu, MASc, University of Victoria
Zhenpeng Zhao, PhD student, University of Alberta

3. PIMS Visitors:

Due to the major events on our international conference and its afterwards summer school, our budget for PIMS visitors this year is very limited. To efficiently use PIMS visitor fund, all the visitors this year are in fact majorly supported by other sources and PIMS visitor fund is used as a supplementary fund to support as many visitors as possible. Since much more funds will be available for supporting visitors in 2012, more visitors will visit various CRG members in 2012.

1. Philippe Angot, University of Marseille, November 26-Dec. 2, 2010, hosted by Peter Minev.

2. Amir Averbuch, Tel Aviv University, July 17-July 29 2011, hosted by Elena Braverman.

3. Li-Qun Cao, Chinese Academy of Science, July 29-August 25, hosted by Rong-Qing Jia and Yau Shu Wong.

4. Raymond Chan, Hong Kong Chinese University, August 21-August 28, hosted by Rong-Qing Jia and Yau Shu Wong.

5. Song Li, Zhejiang University, China, July 29--August 20, 2011, hosted by Bin Han.

6. Qun Mo, Zhejiang University, China, July 25--August 28, 201, hosted by Bin Han.

7. Yuesheng Xu, Syracuse University, USA, August 21-August 25, hosted by Rong-Qing Jia.

8. Xiaosheng Zhuang, Osnabruck University, Germany, July 23-Aug. 13, 2011, hosted by Bin Han.

Some collaborations between CRG members and visitors:
Raymond Chan is an expert in numerical linear algebra and applications to signal and image processing. He successfully developed computational methods based on Block Toeplitz with Toeplitz Blocks preconditioning. During his visit, Yau Shu Wong explores the possible to extend this technique for large scale reconstruction of magnetic data in geophysical applications. Li-Qun Cao and Yau SHu Wong continue the collaboration on multiscale computations for problems in composite materials.

The visitors Qun Mo, Song Li, and Xiaosheng Zhuang have been working with Bin Han on the problem of tight framelets with filter coefficients in algebraic number fields and some interesting initial results have been obtained. This contributes to theory of wavelet frames. In particular, we plan to explore the applications of such tight framelets in signal denoising and image processing as future collaboration.

Rong-Qing Jia and visitor Yuesheng Xu have considered future collaboration research on image processing. In particular, they investigated possible applications of the wavelet method to numerical solutions of integral equations related to image deblurring.

4. Collaborations and Research Progresses of CRG members:

Michael Adams at the University of Victoria:
The research group at the University of Victoria has been working on triangle-mesh representations of images. This work has involved: 1) developing new mesh models for images; 2) devising effective methods for the selection of the parameters for these models for a given image (i.e., the mesh-generation problem); and 3) technique for efficiently encoding these models (i.e., the data compression problem). Two of my graduate students (Xi Tu and Ping Li) and myself have been active on this project.

Xi Tu has been working on mesh models of images that explicitly represent image discontinuities and the corresponding techniques for selecting the parameters of these models for a given image (i.e., the mesh-generation problem). His proposed models are based on constrained Delaunay triangulations. Ping Li has been working on mesh-generation techniques for mesh representations of images based on data-dependent triangulations. My work has focused on mesh representations of images based on Delaunay triangulations as well as the coding of such representation.

Elena Braverman at the University of Calgary:
With PhD student Md. Kamrujjaman, we study population dynamics models with various types of diffusion described by parabolic partial differential equations. Numerical modeling and simulations for these models involves both finite difference and spectral methods.

Tom Duchamp at University of Washington:
This is joint work with Thomas Yu and Gang Xie. We are studying manifold-valued subdivision schemes modeled on linear subdivision schemes, with particular attention to their smoothness properties. These schemes are modeled on linear subdivision schemes. It is known that if the nonlinear scheme yields C^k curves if is satisfies a "C^k-proximity condition" to the linear model. In the paper described below, we show that for an important class of schemes introduced by Donoho, the proximity conditions have constrain the geometry and topology of the target manifold.

The proximity conditions are known to be sufficient for C^k-smoothness. Yu and his students have given numerical evidence that they are also necessary conditions. My current project with Yu and Xie is to prove necessity for a large class of non-linear schemes. We have already obtained partial results. We made some progress on this project this summer in Edmonton. Yu plans to spend part of his upcoming sabbatical (2012-2013) at the University of Washington, so that we can continue this research.

We have recently submitted one paper for publication: *Single Basepoint schemes for manifold-valued data: time-symmetry without space-symmetry*. We establish smoothness results for a class of nonlinear subdivision schemes, known as the *single basepoint manifold-valued subdivision schemes,* which shows up in the construction of wavelet-like transform for manifold-valued data. This class includes the (single basepoint) Log-Exp subdivision scheme as a special case; and the class is defined base on replacing the exponential map by a so-called retraction map f. It is known that any choice of f would yield a scheme that C2 as long as the underlying linear scheme is C2. However it was found by Navayazdani and Yu that a specific condition on f has to be imposed in order to guarantee the next higher order, i.e. C3, equivalence. Underlying this condition is a certain tensor P_f associated with f, and the condition is that this tensor vanishes. It was also shown that, in a symmetric space setting, the exponential map always satisfies this condition.

We gave a geometric interpretation of this tensor. We showed that any retraction map f defines a torsion-free affine connection, which in turn defines an exponential map. The condition $P_f=0$ is shown to be equivalent to the condition that f agrees with the exponential map of the connection up to the 3rd order. In particular, when f is, itself, the exponential map of a connection, one recovers the original connection. It then follows that the condition P_f=0 is satisfied in a setting much more general than symmetric space. We also proved that, under the additional assumption that the subdivision rule satisfies *a time-reversal symmetry*, C4 equivalence holds without any constraint on the fourth order behaviour of f. However, our analysis strongly indicates that Ck equivalence is impossible on a non-flat manifold when k>4.

Bin Han at the University of Alberta:
The current research of Bin Han is on the understanding of wavelet analysis from the point of view of distribution theory in the frequency domain and on the study of directional framelets with particular applications in image processing. Though wavelet analysis has been extensively developed for many years now, it faces several challenging problems. First of all, though wavelets have been regarded as an efficient tools in data processing, it has been shown that it is not the most efficient representation in order to capture more common singularities in high dimensions other than point singularity (for which wavelets have been shown to be the best possible way to capture), for example, the directional edges in images. This requires the further development of wavelet analysis in dimensions higher than one. One way to overcome the shortcomings of wavelets to handle high dimensional data is to study directional framelets. Working with several visitors and student such as Xiaosheng Zhuang, Zhengpeng Zhao, and Qun Mo. we are currently development the theory of directional framelets and test its usefulness in the setting of image denoising. Currently, Elena Braverman (CRG leader at University of Calgary) and Bin Han are collaborating together to try to recruit a CRG PIMS PDF to work together on the applications of wavelets including directional framelets and their applications to numerical algorithms.

Another possible way to achieve directionality is to consider complex wavelets. Currently, Zhenpeng Zhao (PhD student) is working with on to develop a comprehensive theory for dual tree complex wavelets and their applications to signal and image processing. At the mean time, Yua Shu Wong (another CRG member at the University of Alberta) and Bin Han are working together to try to apply such complex wavelets and directional framelets in some industrial problems, collaborating with an industrial partner.

Peter Minev at the University of Alberta:
Development of a massively parallel direction-splitting algorithm for the incompressible Navier-Stokes equations. Currently the algorithm is developed and analyzed in the case of simple domain geometry and it demonstrated exceptional parallel efficiency as well as extremely high computational speed. Currently we are developing it for complex and moving geometries. The applications that we have in mind are related particulate flows, multiphase flows in oil separation processes, atmospheric and oceanic flows.

I would qualify the algorithm described above as a breakthrough result because it opens the door for extremely large-scale computations of important problems. Groups at Texas A&M University, a CNRS laboratory in Orsay, France, and at the Fraunhofer Institute for Industrial Mathematics in Kaiserslautern, Germany, have started utilizing the algorithm for various applications.

Bernie Shizgal at University of British Columbia:

The main thrust of the research in the Chemistry Department at the University of British Columbia (UBC) is directed towards the development of numerical algorithms in scientific computing based on spectral methods with grids defined by nonclassical polynomials, as well as with Fourier series, splines and wavelets. The numerical methods are applied to the solution of kinetic equations such as the Boltzmann, Fokker-Planck, and Schr¨odinger equations. These formalisms form the basis for numerical simulations for a large number of physical phenomena in chemistry, physics, astronomy, engineering as well mathematical biology. A brief overview of several research endeavors is discussed below:

1. Fourier methods in the solution of the Vlasov equation in ionospheric physics:

The evolution of an ensemble of charged particles is given by the Vlasov equation with a steady uniform magnetic field and a perpendicular electric field that oscillates in space and time. The Vlasov equation is solved with a Fourier-Hermite spectral method and a particle simulation, and the energization of ions in a geophysical context is studied. The energization of the ion distribution is related to stochastic heating arising from the chaotic dynamics associated with the equations of motion for the particles in the given fields as studied with a particle Monte Carlo simulation (Gibelli, Shizgal and Yau, Comp. Math. Appl. 59 (2010) 2566-2581). We are currently involved with the inclusion of the altitude dependence of the distribution function and a study of the formation of “conics” in the terrestrial ionosphere in conjunction with the upcoming ePOP satellite mission (http://mertensiana.phys.ucalgary.ca/) scheduled for launch in December 2011. Dr. Gibelli of the Dipartimento di Matematica of the Politecnico di Milano is an international collaborator on this project and will visit UBC in July/August 2012. This study with a direct numerical solution based on spectral methods in comparison with Monte Carlo simulations is ongoing.

2. A spectral and Fourier analysis of the nonlinear and linearized Boltzmann equations; nonthermal oxygen in terrestrial atmosphere.

Energetic oxygen atoms are produced in the terrestrial atmosphere as products of the dissociative recombination reaction. The characterization of the energy distribution of O atoms versus altitude is determined from the linear Boltzmann equation at low altitudes and the nonlinear Boltzmann equation at high altitudes. A comparison of the solutions of the linear and nonlinear equations is of fundamental interest independent of this particular application. The methods of solution employed include spectral methods involving the expansion of the speed or Laguerre polynomials. This work is carried out in collaboration with Dr. Reinel Sospedra-Alfonso, a postdoctoral fellow at UBC and is also related to the ePOP satellite mission.

3. Splines and wavelets in kinetic theory and computer graphics.
Solutions of the Boltzmann equation using splines have been used by Siewert (J. Quant. Spectros. & Rad. Transf. 74 (2002) 789-796; Crouseilles, Latu & Sonnendrcker, J. Comput. Phys. 228 (2009) 1429-1446), and at UBC by Khurana and Thachuk (Journal of Chemical Physics, submitted). These solution methodologies for kinetic theory are new and find important application to computer graphics and rendering (Alim, Entezari & M¨oller, IEEE Trans. Vis. and Comp. Graphics 15 (2009) 630-641) also related to lattice Boltzmann method with an important impact on graphics and visualization techniques. A spectral method based on speed polynomials was recently compared with Hermite spline method by Siewert (Shizgal, AIP Conf. Proc. 1333 (2011) 986-991). The comparisons of these different numerical methodologies is ongoing.

4. Resolution of Gibbs' phenomena.
Images in science and engineering are often stored as Fourier data. The reconstruction of the original data or images from such Fourier data is contaminated by Gibbs phenomena (Gottlieb, Jung & Kim, Commun. Computat. Phys. 9 (2011) 497-519). It arises owing to the lack of convergence of the Fourier series of nonperiodic functions at discontinuous points and does not disappear if the terms in the series are increased. A new method for the resolution of Gibbs phenomena referred to as the Inverse Polynomial Reconstruction Method (IPRM) was developed by Shizgal & Jung (J. Comp. Appl. Math. 161 (2003) 41-65). It was shown that the IPRM provides an exact resolution of Gibbs’ phenomena if the original function is a polynomial. Other methods such as filtering, Pade approximants and radial basis functions (Advances in the Gibbs Phenomenon Abdul J. Jerri, Ed., Sampling Publishing, Potsdam, New York 2011) are currently adapted to many applications including numerical solution of partial differential equations, image processing, and machine learning. We are currently involved in a detailed comparison of these and other resolution methods for Gibbs’ phenomenon including edge detection and tomography. The main objective is to apply the IPRM with edge detection to the resolution of magnetic resonance images as a preprocessing step (Landi & Piccolomini, J. Math. Imaging Vis. 26 (2006) 27-40). We will use simulated brain phantom data from McConnell Brain Imaging Center at the Montreal.

Yau Shu Wong at the University of Alberta:
Yau Shu Wong establishes collaboration with TerraNotes Ltd - a geoscience company based in Edmonton, Alberta. Two MITACS-Terranotes Internships are awarded to carry out to develop efficient computational techniques for forward and inverse geophysical models.

Ozgur Yilmaz at University of British Columbia:
The current research program of Ozgur Yilmaz focuses on various mathematical problems in the theory of sparse approximations and compressed sensing. The main focus is in the following directions:

(1) *Compressed sensing and quantization*
Recent advances have established compressed sensing as an effective sampling theory for acquisition of high dimensional sparse vectors from few linear measurements. The vast majority of the results in the literature assume that the compressive samples are real numbers, and a comprehensive quantization theory for compressed sensing has been missing. Together with collaborators, we recently showed that we can successfully employ noise-shaping Sigma-Delta quantizers for compressed sensing. We proved that, by adopting a two-stage approach involving the use of appropriate Sobolev dual frames in the reconstruction, Sigma-Delta quantizers utilize the inherent redundancy of compressed sensing more efficiently than ”any” round-off type quantization algorithm, at least in the case of Gaussian measurement matrices. The original framework we introduced is especially successful if the underlying signals are exactly sparse. Currently, we are considering the cases when there is measurement noise (in addition to the quantization error) and when the signal to be acquired is not strictly sparse, but compressible. We already have devised alternative reconstruction methods that effectively handle this more general setup. This research line has the purpose of establishing compressed sensing as a feasible source coding method and incorporating this novel sampling technique into the technology of analog-to-digital converters.

(2) *Sparse recovery algorithms*
Compressed sensing is a powerful "non-adaptive" signal acquisition paradigm. After making the initial assumption that the high-dimensional signals to be acquired are sparse or compressible, one constructs a universal sampling method (i.e., a measurement matrix) that will provide sufficient information to recover the underlying signal exactly or approximately. Typically, the reconstruction algorithm (e.g., 1-norm minimization) is also non-adaptive---i.e., it does not utilize any additional information about the signal and can be used to estimate any sufficiently sparse or compressible signal. In various applications, however, there is prior information that can be exploited to improve both the recovery quality (i.e., get better reconstruction with the same number of measurements) and the compressive sampling rate (i.e., reduce the number of

measurements without compromising the recovery quality). In this research line, we devised two such methods: (i) a recovery algorithm based on weighted 1-norm minimization, and (ii) an adaptive compressive sampling paradigm. Our results are constructive (i.e., we come up with specific recovery algorithms) and rigorous (i.e., we specify conditions under which we can establish theoretical recovery guarantees).

(3) Applications to exploration seismology
Together with Felix Herrmann (EOS, UBC)---who is a member of this CRG---and Michael Friedlander (CS, UBC), we run a research program that focuses on leveraging various techniques from computational harmonic analysis as well as sparse approximations and compressed sensing in order to improve the state-of-the-art seismic signal processing and imaging technology. Our project is supported by industry as well as a CRD grant from NSERC. For example, our algorithms I have described above have been successfully implemented to tackle some important acquisition and processing problems in exploration seismology.

5. Some publications in 2011:

Most if not all of the following publications are supported by sources other than PIMS. Since our CRG just started, publications directly related to PIMS CRG are almost impossible at this stage. Nevertheless, we list them here to indicate research activities of our CRG members.

Michael Adams at the University of Victoria:

1. M. D. Adams, "A Flexible Content-Adaptive Mesh-Generation Strategy for Image Representation," IEEE Transactions on Image Processing, Vol. 20 (2011) No. 9, 2414-2427.

2. M. D. Adams, "An Incremental/Decremental Delaunay Mesh-Generation Framework for Image Representation," in Proc. of IEEE International Conference on Image Processing, Brussels, Belgium, (2011) 193-196.

3. X. Tu and M. D. Adams, "Image Representation Using Triangle Meshes with Explicit Discontinuities," in Proc. of IEEE Pacific Rim Conference on Communications, Computers and Signal Processing, Victoria, BC, Canada, (2011), 97-101.

Elena Braverman at the University of Calgary:

1. E. Braverman and B. Karpuz, On oscillation of differential and difference equations with non-monotone delays, Applied Mathematics Computation. Vol. 218 (2011), 3880-3887.

2. L. Berezansky and E. Braverman, On some constants for oscillation

and stability of delay equations, Proceedings of American Mathematical Society, Vol. 139 (2011), No. 11, 4017-4026.

3. E. Braverman and S. H. Saker, On a difference equation with exponentially decreasing nonlinearity, Discrete Dynamics in Nature and Society, (2011), Article ID 147926.

4. L. Korobenko and E. Braverman, On permanence and stability of a logistic model with harvesting and a carrying capacity dependent diffusion, Journal of Nonlinear Systems and Applications, Vol. 2 (2011), No. 1-2, 9-15.

5. L. Berezansky, E. Braverman and A. Domoshnitsky, On nonoscillation of systems of delay equations, Funkcialaj Ekvacioj, Vol. 54 (2011), 275-296.

6. L. Berezansky and E. Braverman, Preservation of exponential stability for equations with several delays, Mathematica Bohemica, Vol. 136 (2011), No. 2, 135-144.

7. L. Berezansky and E. Braverman, Stability of linear differential equations with a distributed delay, Communications on Pure and Applied Analysis, Vol. 10 (2011), No. 5, 1361-1375.

8. L. Berezansky and E. Braverman, New stability conditions for linear differential equations with several delays, Abstract and Applied Analysis, (2011), Article ID 178568.

9. L. Berezansky and E. Braverman, New stability conditions for linear difference equations using Bohl-Perron type theorems, Journal of Difference Equations and Applications. Vol. 17 (2011), No. 5, 657-675.

10. L. Berezansky and E. Braverman, On nonoscillation of advanced differential equations with several terms, Abstract and Applied Analysis, (2011), Article ID 637142.

11. E. Braverman and B. Karpuz, Nonoscillation of second-order dynamic equations with several delays, Abstract and Applied Analysis, (2011), Article ID 591254.

Bin Han at the University of Alberta:

1. B. Han, G. Kutyniok, and Z. Shen, Adaptive multiresolution analysis structures and shearlet systems, SIAM Journal on Numerical Analysis, Vol. 49 (2011), 1921--1946..

B. Han, Symmetric orthogonal filters and wavelets with linear-phase moments, Journal of Computational and Applied Mathematics, Vol. 236 (2011), Issue 4, 482--503.

B. Han, Q. Mo, and Z. Shen, Small support spline Riesz wavelets in low dimensions, Journal of Fourier Analysis and Applications, Vol. 17 (2011), 535--566.

S. S. Goh, B. Han and Z. Shen, Tight periodic wavelet frames and approximation orders , Applied and Computational Harmonic Analysis, Vol. 31 (2011), Issue 2, 228--248.

Xiaobo Li at the University of Alberta:

1. D. Wang, F. Yi, and X. Li, "Probabilistic visual secret sharing schemes for grey-scale images and color images", Information Sciences, Vol.181, (2011) 2189-2208.

2. D. Wang, L. Dong, and X. Li, "Towards shift tolerant visual secret sharing schemes", IEEE Transactions on Information Forensics and Security, Vol.6, (2011) No.2, 323-337.

Peter Minev at the University of Alberta:

1. J.L. Guermond, P. Minev, A. Salgado, Convergence Analysis of a Class of Massively Parallel Direction Splitting Algorithms for the Navier-Stokes Equations in simple Domains. Mathematics of Computation, In press.

2. A. Roshchenko, W.H. Finlay, P. D. Minev, The Aerodynamic Behaviour of Fibers in a Linear Shear Flow, Aerosol Science Technology, Vol. 45 (2011), 1260-1271.

3. J.L. Guermond and P. Minev, Start-up flow in a three-dimensional lid-driven cavity by means of a massively parallel direction splitting algorithm. International Journal of Numerical Methods in Fluids, In Press.

4. J.L. Guermond and P. Minev, A new class of massively parallel direction splitting for the incompressible Navier-Stokes equations. Computer Methods in Applied Mechanics and Engineering, Vol. 200 (2011), 2083--2093.

Bernie Shizgal at the University of British Columbia:

1. Sospedra-Alfonso, Reinel and Shizgal, Bernie D., Kullback-Leibler entropy in the electron distribution shape relaxation for electron-atom thermalization, Physical Review E, Vol. 84 (2011) 041202.

2. Shizgal Bernie D., Pseudospectral Methods of Solution of the Linear and Linearized Boltzmann Equations, Transport and Relaxation AIP Conference Proceeding, Vol. 1333 (2011) 986-991.

3. Sospedra-Alfonso, Reinel and Shizga,l Bernie D., Henyey-Greenstein model in the shape relaxation of dilute gas mixtures, Transactions on Theoretical and Statistical Physics, (submitted).

Yau Shu Wong at the University of Alberta:

1. Y. A. Zhang, L. Cao and Y.S. Wong, Multiscale computations for 3D time-dependent Maxwell's equations in composite materials, SIAM Journal on Scientific Computing, Vol. 32 (2010), 2560-2583.

2. J. Deng, C. A. Popescu and Y. S. Wong. Stochastic collocation method for secondary bifurcation of a nonlinear aeroelastic system, Journal of Sound and Vibration, Vol. 330 (2011), 3006-3023.

3. J. Deng, C. Adela Popescu and Y. S. Wong. Uncertainty investigations in nonlinear aeroelastic systems, Journal of Computational and Applied Mathematics, Vol. 235 (2011), 3910-3920.

4. Y. S. Wong and G. Li. Exact finite difference schemes for solving Helmholtz equation at any wavenumber, International Journal for Numerical Methods in Engineering - Series B, Vol. 2 (2011), No. 4, 91-108.

Ozgur Yilmaz at the University of British Columbia:

1. A. Powell, J. Tanner, Y. Wang, and O. Yilmaz, Coarse quantization for random interleaved sampling of bandlimited signals, ESAIM: Mathematical Modelling and Numerical Analysis, In Press.

2. M.P. Friedlander, H. Mansour, R. Saab, and O. Yilmaz, Recovering compressively sampled signals using partial support Information, IEEE Transactions on Information Theory, In Press.

3. H. Mansour and O. Yilmaz, Weighted 1-norm minimization with multiple weighting sets, SPIE Wavelets and Sparsity XIV, San Diego, Aug 2011.