

Fields Institute Annual Report 2010-2011

Full Reports for Lectures and Special Events, GSA, CMM, CIM, and Math Education

LECTURES AND SPECIAL EVENTS

Fields-Carleton Distinguished Lecture Series: Donald Dawson

March 23 and 25, 2011, Held at Carleton University

On March 23 and 25, 2011, Carleton University was proud to have our colleague Don Dawson as Distinguished Lecturer in the Fields-Carleton Distinguished Lecture Series.

Dawson is a leading researcher in probability and stochastic processes and their applications to complex systems, statistical physics, genetics and evolutionary biology. He served as Director of the Fields Institute in 1996-2000 and as the President of the Bernoulli Society for Mathematical Statistics and Probability for 2003-2005. He is a Fellow of the Royal Society of Canada, Institute of Mathematical Statistics and International Statistical Institute and received a Max Planck Award for International Cooperation from the Humboldt Foundation in 1996, the CRM-Fields prize in 2004, and an honorary Dr.Sci. degree from McGill University in 2005. He was elected to the Royal Society (London) in 2010.

In his public lecture, Dawson presented some historical perspectives on three major developments in probability theory and explained how these had been motivated by scientific phenomena in which randomness plays an essential role. The first of these is the rise of stochastic analysis. This can be traced back to the discovery of Brownian motion by Bachelier in 1900 in his modelling of the fluctuations of prices on the Paris Bourse, and to Einstein's revolutionary paper on the Brownian motion of a pollen particle suspended in a liquid as a result of random molecular bombardment. Following the seminal work of Wiener and Lévy, the study of Brownian motion developed into a rich mathematical theory and Brownian motion has become a fundamental mathematical object that arises throughout the sciences, sometimes in surprising ways. The next step in the development of stochastic analysis was the remarkable discovery by Kiyoshi Itô of the stochastic integral which made possible the development and application of stochastic differential equations in the physical and biological sciences, and which was recognized by the award of the first Gauss Prize for mathematical discoveries having an impact on science and society by the International Mathematical Union in 2006. In particular the stochastic calculus played a central role in the development of mathematical finance based on ideas going back to Bachelier. The most celebrated of these is the Black-Scholes formula which resulted in the award of the Nobel Prize to Merton and Scholes in 1997. The trading of options based on these methods has grown to a volume which exceeded 3 billion contracts in 2010. Dawson recounted some of the issues surrounding

the 2007-2008 financial meltdown and explained how this illustrates the mathematical challenges of complex highly interactive systems.

He then introduced the development of Markov dynamics going back to the work of Markov in Saint Petersburg and of Kolmogorov and his school in Moscow in the 1930's. This is based on the basic notion of conditional probabilities and the resulting class of Markov chains plays an essential role in the modelling of population genetics, communications networks and many other fields. He also mentioned the role of Markov chains in the creation of information theory by Claude Shannon who is often regarded as the father of the information age. He went on to describe how this, together with the Monte Carlo method introduced by Ulam, von Neumann and Metropolis in 1946, led to the development of the Markov-Chain Monte Carlo method which has become a powerful tool in statistics, machine learning and expert systems. He introduced the main idea with an example due to Diaconis which illustrates how randomness can be used to find a solution among a huge number of possibilities by random sampling and iteratively choosing solutions which are better according to some measure but also allow for keeping inferior ones with some probability and explained how this method can be refined using the method of simulated annealing.

He then described the class of random graphs introduced by the Hungarian mathematicians Paul Erdős and Alfréd Rényi, and the current developments in more complex random graphs having the “small worlds property”. He gave a brief introduction to the problem of percolation and the breakthroughs over the past decade due to Schramm, Lawler, Smirnov and Werner, which were recognized by the awarding of the Fields Medal to Werner (2006) and Smirnov (2010).

Dawson concluded his first lecture by commenting on current challenges to stochastic modelling and analysis posed by complex nonlinear random systems as illustrated by the examples of financial markets, ecosystems and the spatial spread of epidemics.

His second lecture, delivered to a more mathematically inclined audience, focused on spatial structures and universality classes which arise in the study of biological systems distributed in space which involve randomness and nonlinearity. The basic starting point of this development is the classical Galton-Watson branching process and the corresponding spatial model, namely, the branching random walk. The measure-valued process which arises as the renormalized limit of a system of branching random walks on the Euclidean lattice is the super-Brownian motion (SBM). The process is characterized by means of the Laplace transform of the marginal distributions which is obtained in terms of the solution of a nonlinear partial differential equation. A more complete picture of the Galton-Watson process is given by the corresponding family tree. A tree can be represented by its contour function and then associated to an excursion of a random walk. Over the past twenty years the structure and evolution of these genealogical trees has been extensively studied. In the early 1990's Aldous discovered that the renormalized limit of the branching tree is given by a *continuum random tree*, which corresponds to a Brownian excursion. The CRT can be embedded into \mathbf{R}^d with image measure given by ISE which is the total occupation time measure of a super-Brownian excursion. The nature of these objects is highly dimension dependent related to the intersection

properties of a SBM. For example the ranges of two super-Brownian motions in \mathbf{R}^d intersect if and only if $d \leq 7$ and the support of ISE is a tree if and only if $d \geq 8$.

The classical invariance principle implies that the scaling limit of a large class of discrete stochastic processes is given by Brownian motion. Expanding on this, the idea that the large space and time scale behaviour of many physical systems can be classified into “universality classes” and that the structure of such classes is highly dimension-dependent, is one of the great developments in statistical physics. In the realm of population processes, universality classes associated to SBM and ISE have emerged from a surprising range of particle systems and random combinatorial objects. Over the past few years a *super-Brownian invariance principle* due to Cox, Durrett and Perkins has been used, for example, to determine parameter regimes for coexistence for spatial Lotka-Volterra systems, and the critical behaviour of spatial epidemics. This leads to the questions as to why rescaled population processes converge to SBM and how to identify analogous universality classes for multitype systems? He described his joint work with Andreas Greven to develop an approach to these questions in which the spatial structure is simplified but in such a way as to retain certain potential theoretic properties. This involves modelling a population as a hierarchy of subpopulations at different levels with exchangeable dynamics at each level. In the simplest case this corresponds to the mean-field approximation of statistical physics and leads to a deterministic partial differential equation, the McKean-Vlasov equation, which characterizes the limiting empirical distribution as the population size goes to infinity. The full hierarchical mean-field analysis has been used to identify universality classes of critical stochastic mechanisms at the small scale and large scale limits including branching, catalytic branching, mutually catalytic branching and Wright-Fisher diffusion. A recent application of this approach is the analysis of the emergence of rare mutants in a spatial population. The latter provides an example of a nonlinear stochastic system in which randomness remains, even at the macroscopic level.

He concluded by describing the mathematical challenges posed by questions related to the emergence of new levels of complexity and organization in systems involving stochastic, spatial and nonlinear aspects.

Both lectures were truly outstanding insightful presentations that made a lasting impression on the audience.

Barbara Szyszkowicz (Carleton)

Nathan and Barbara Keyfitz Lecture in Mathematics and the Social Sciences:

George Lakoff

March 14, 2011, Held at the Fields Institute

George Lakoff's Nathan and Beatrice Keyfitz Lecture, *The Cognitive and Neural Foundation of Mathematics: The Case of Gödel's Metaphors*, was held at the University of Toronto on March 14, 2011. It was a highlight of the *Workshop on Semiotics, Cognitive Science and Mathematics*. Lakoff outlined a fascinating, albeit controversial, perspective of how mathematicians form their proofs, focusing on Gödel's famous

indeterminacy proof. Lakoff argued that the proof had a basic metaphorical structure in the way it was argued and laid out; this provides further evidence in favor of his working hypothesis that mathematical ideas originate in figurative cognition—a hypothesis he put forward with Rafael Núñez in a book entitled *Where Mathematics Comes From: How the Embodied Mind Brings Mathematics into Being*.

Lakoff has been a professor of linguistics at the University of California at Berkeley since 1972. He is well-known in linguistics as an originator of a theory of language known generally as *conceptual metaphor theory*, which he developed initially with philosopher Mark Johnson in their book, *Metaphors We Live By*. The book described what is, arguably, a veritable discovery of how the human brain generates and comprehends language. It does so through a process of association that reveals itself in figures of speech, which are tokens of how the brain blends experience with abstract thoughts to produce concepts with a manifest metaphorical structure. Thus, a simple metaphorical utterance—such as “*That mathematician is a snake*”—is really just a token of a higher-level cognitive formula, namely that people are animals. The former is a linguistic metaphor, the latter a conceptual metaphor. The number of significant and corroborative research findings brought about by the discovery of conceptual metaphors has been plentiful; even today, linguists of a different theoretical persuasion cannot avoid making reference to Lakoff’s ideas. As Lakoff and Núñez argued in 2000, mathematical ideas are products of the same conceptual metaphorical system that generates language. The claim is not as far-fetched as it seems, especially under the assumption that language and mathematics are cognitively interrelated and that the conceptual basis of language is metaphorical, even though we do not consciously realize this as we speak and carry out cognitive activities, such as solving mathematical problems.

Lakoff began his lecture by asserting that mathematics is a creation of the human mind, not something that exists in the absolute as Plato and current-day Platonists would maintain. He then argued his hypothesis by looking at Cantor’s proof that there are more irrationals than rationals, which, he claimed, was guided by a simple metaphor—the familiar geometrical image of a diagonal. This metaphor is visible in Cantor’s diagrammatic layout—a square array of numbers through which a diagonalized subset comes into view to show the theorem’s tenability.

Gödel’s proof is the result of an analogous metaphorical argumentation. In his famous 1931 paper, Austrian-born American mathematician Kurt Gödel proved that within any formal logical system there are results that cannot be proved or disproved. Such results are said to be undecidable. A consequence of Gödel’s brilliant demonstration is that any logically defined system, even one as familiar as arithmetic, might give rise to contradictory results. How did Gödel come up with this ingenious proof?

Lakoff claims that Gödel must have been inspired and guided unconsciously by Cantor’s diagonalization and one-to-one matching metaphors, leading him to imagine three metaphors of his own. Lakoff’s reasoning went schematically as follows: Gödel’s first metaphor, called the Gödel Number of a Symbol, can be seen in his argument that a symbol (in any formal system) is the corresponding number in the Cantorian one-to-one

matching system, whereby any two sets of symbols can be put into a one-to-one relation. Gödel's second metaphor, called the Gödel Number of a Symbol in a Sequence, was his reasoning that the n th symbol in a sequence is the n th prime raised to the power of the Gödel Number of the Symbol. Gödel's third metaphor, called Gödel's Central Metaphor, was his proof that a symbol sequence is the product of the Gödel numbers of the symbols in the sequence.

Lakoff gave a detailed argument, and then concluded by entering metaphorically into Gödel's brain, claiming that he came to his proof through a "blending process." A blend is formed when the brain identifies two distinct entities in different neural maps as the same entity in a third neural map; the three maps together constitute the blend. In the metaphor *That mathematician is a snake*, the two distinct entities are "the mathematician" and "the snake." Their blending together is guided by the inference that people are animals. This is the final touch to the conceptual blend, which keeps the two entities distinct in different neural maps, while identifying them as a single entity in the third map. A metaphorical blend occurs when the entities in the two maps are the source (animals) and target (people) of a metaphor. Gödel's metaphors are neural circuits linking a number source to a symbol target. In each case, there is a metaphorical blend, with a single entity composed of both a number and a symbol sequence. When the symbol sequence is a formal proof, a new mathematical entity appears— a "proof number."

"So what?" Lakoff asked as part of his final remarks. If he is correct, the answer would be "A lot!" Proof and mathematical discoveries in general are located in the same neural circuitry that supports all cognition. It is this circuitry that allows us to interpret meaningless formal logical expressions as talking about themselves. Although the diagonal array used by Gödel was based only on numbers, the interpretation of the crucial sentence in the array had nothing to do with numbers, sums, or products. It was only about provability in a formal system.

Lakoff's lecture gave a great deal of insight into how mathematics works inside the brain and how it is interconnected with other faculties through blending and associative processes. Mathematics works when it has meanings that fit our basic experiences of the world, such as quantity, space, motion, force, change, mass, shape, probability, and self-regulating processes.

Marcel Danesi (Toronto) and Mariana Bockarova (Harvard)

Coxeter Lecture Series: Neil Ferguson

August 4–6, 2010, Held at the Fields Institute

The 2010 Summer *Thematic Program on the Mathematics of Drug Resistance in Infectious Diseases* was held at the Fields Institute during July and August. In association with this thematic program, Professor Neil Ferguson was invited to the Fields Institute to deliver the Coxeter Lecture Series on *Mathematical modelling of emerging infectious disease epidemics and their control*.

Ferguson, a Professor of Mathematical Biology in the Division of Epidemiology, Public Health, and Primary Care of the Medical School at Imperial College, is a world leader in the use of mathematical models in infectious disease epidemiology. He is the Director of the MRC Centre for Outbreak Analysis and Modelling.

In the first lecture, Ferguson reviewed the development of outbreak modelling over the last two decades and discussed the drivers which lead to more complex computational simulations being increasingly used replacing simpler compartmental models of disease transmission. The second lecture discussed ways in which modelling can be optimally used to assist public health policymakers in their planning for and reaction to emerging infectious disease threats—an issue on which Ferguson is an expert, and which was of great interest to the thematic program participants. The third lecture focused on the potential impact of antiviral resistance during an influenza pandemic. He offered several explanations for new findings that show the degree to which previous risk assessments concerning antiviral resistance in influenza pandemics have been over-pessimistic. In the lecture, Ferguson touched on the critical issue of the dependence of the final impact of resistance during a closed epidemic on the transmissibility of a sensitive and resistant virus, the mutation rate from one type to the other, and the level of seeding of both viral types at the beginning of the epidemic. He argued that resistance is not likely to entail a substantial reduction of effectiveness of antivirals during the start of a pandemic, but that intensive drug use in this phase can lead to a higher degree of resistance in later epidemics. His concluding remark that “simple models suggest antiviral resistance could be a major issue in the first wave of a new pandemic, but allowing for spatial heterogeneity reduces speed of resistance” strongly echoed the theme of transmission heterogeneity of the two-week block of this entire thematic program on mathematics for drug resistance.

Jianhong Wu (York)

Coxeter Lecture Series: Shiri Artstein-Avidan

September 17, 20, 21, 2011, Held at the Fields Institute

Shiri Artstein-Avidan’s lectures provided a new view of some of the classical mathematical transformations and maps, such as polarity, the Fourier transform, the Legendre transform, the derivative and others. These are so commonly used in mathematics and in mathematically inclined fields that one rarely gives them a second thought. However, it is a natural question to ask why these transforms are defined the way they are. How little do we have to posit to get full definitions of these transforms? Several new and fundamental answers to these questions were given by Shiri Artstein-Avidan in her Coxeter Lecture.

Shiri Artstein-Avidan is an Associate Professor at the School of Mathematical Sciences of Tel Aviv University. She completed her PhD there in 2004 and then moved to the US as a Veblen Research Instructor at Princeton University and the Institute for Advanced Study. In 2006, she returned to Tel Aviv University. She has worked on a wide array of question in geometry and analysis ranging from the concentration of measure phenomenon in the asymptotic theory of Banach spaces to symplectic capacities. She is

perhaps best known for her solution, jointly with Keith Ball, Franck Barthe, and Assaf Naor, of the problem of the monotonicity of entropy, for her joint work with Stanislaw Szarek and Nicole Tomczak-Jaegermann on the duality of metric entropy, and for the results she presented in her Coxeter Lecture.

In her Coxeter Lecture, the starting point was polarity a central concept in geometry, functional analysis and in many other mathematical fields. What are the most basic properties which characterize the polarity transform – apart from its concrete definition by formula? It is easy to see that polarity is an order reversing involution, and it was proved by Karoly Böröczky, Jr., and Rolf Schneider – answering a question by Vitali Milman – that up to linear terms, this property characterizes the polarity transform completely. Namely, polarity is – up to linear terms which can be thought of as changes of coordinates in the base and target space – the only way to define a transform on convex sets that is order reversing and involutive, that is, when applied twice it will return the original object. The Böröczky-Schneider Theorem belongs to a group of important results in geometry ranging from Hugo Hadwiger’s celebrated characterization theorem of intrinsic volumes and Semyon Alesker’s classification of translation invariant valuations, to Peter M. Gruber’s characterization of endomorphisms of the lattice of convex sets.

In joint work with Vitali Milman, Artstein-Avidan obtained a new family of results now on classes of functions. They showed that the classical Legendre transform can be characterized in a way similar to polarity: up to linear terms, it is the only involution on the class of convex lower semi-continuous functions on \mathbb{R}^n which reverses the (partial) order of functions. Since the Legendre transform has another special property, namely that it exchanges summation of functions with their inf-convolution, this implies that an involution on lower semi-continuous convex functions which reverses order must have this special property. Artstein-Avidan and Milman proved that the opposite is also true, namely any involutive transform (on this class) which exchanges summation with inf-convolution, must reverse order, and, in fact, must be (up to linear terms) the Legendre transform. Thus very minimal basic properties define essentially uniquely a classical transform which traditionally was only defined in a concrete manner.

A similar analysis was performed by Artstein-Avidan jointly with Semyon Alesker and Vitali Milman on the Fourier transform, where the key characteristic is that of exchanging products with convolutions. They proved again that a very basic and everyday used property is sufficient to define this classical transform completely.

The derivate is a slightly different story – the Leibniz law is well investigated and in abstract settings transforms which satisfy this law are called “abstract derivatives”. But the chain rule, again used by all from their very first calculus course, had been less well investigated and it was not known that it characterized the derivative transform up to some obvious additional terms. This classification result was established by Artstein-Avidan in a recent joint work with Herrmann König and Milman.

The above results are only small selections of the results described by Shiri Artstein-Avidan in her Coxeter Lecture. She also presented beautiful recent results obtained jointly with her students Dmitry Faifman, Dan Florentin, and Boaz Slomka. Moreover she was able to give some sense of the proofs and to outline possible future developments.

Monika Ludwig (Vienna University of Technology)

Coxeter Lecture Series: Srinivasa Varadhan

April 13-15, 2011, Held at the Fields Institute

From April 13 to 15, the Fields Institute was fortunate to have S.R.S. Varadhan deliver the Coxeter Lecture Series as part of the Thematic Program on Dynamics and Transport in Disordered Systems. Varadhan, a professor at the Courant Institute of Mathematical Sciences, has long been recognized as one of the world's most influential probabilists. He is known throughout mathematics for his deep insight, and in 2007 he was awarded the Abel Prize "for his fundamental contributions to probability theory and in particular for creating a unified theory of large deviations." He used his three lectures to give a broad overview of large deviations.

Large deviations can be thought of as the study of rare events. Instead of studying the typical behavior of a random system, large deviations focuses on atypical events and asks: Just how rare are they? What happens when they do occur? Precise answers are important, as a wide variety of phenomena turn out to hinge on events with very small probabilities but very large effects.

The first rigorous large deviations results are due to the Swedish actuary Cramér. For an insurance company offering protection against hurricanes, earthquakes, and other calamities, understanding rare events is important. Cramér's work applies to all of these situations, but is easily understood in the context of coin tossing. If we begin with a fair coin, then after a large number of tosses we expect to observe an equal proportion of heads and tails (the typical behavior). There is, however, a small probability of observing a proportion of heads that is different from $\frac{1}{2}$ (a rare event), and the large deviations problem is to compute how quickly this probability decays as more coin tosses are made.

Cramér gave a solution to this problem (and the more general one for sums of independent random variables) in 1937. Thirty years later, Varadhan took the ideas underlying Cramér's work and turned them into a cohesive set of principles with extremely wide applicability. In his first lecture Varadhan explained the abstract principles behind large deviations, strongly emphasizing that they are a guiding point of view rather than a fixed theory. He used the rest of the lecture series to apply this point of view to a series of increasingly complex problems. Each served to illustrate the general principles and the central issues one encounters in applying them.

In Varadhan's general formulation, one specifies a model (like coin tossing) as a sequence of probability measures. There is also an event which, under these measures,

has an exponentially decaying probability. The goal is to compute the rate of decay. Laplace's principle suggests that the rate will be governed by that part of the event where the probability decays slowest; the rate should therefore be an infimum of some function over the event.

Varadhan explained that the strategy is to change the probability measure so that the rare event becomes typical, which yields a simple estimate on the rate of decay. But there are many ways to make the event typical and each comes with an associated cost. This cost is precisely the relative entropy of the new "tilted" measure with respect to the original one. A lower cost gives a better estimate, and the minimal entropy cost over all choices generally gives the correct rate of decay. The minimizer itself encodes how the rare event typically occurs (when it actually does).

He also discussed the importance of the contraction principle. The basic idea is that large deviations for the model's statistics are already encoded in the large deviations for the model itself, so more is gained by trying to compute the latter rather than the former. In the coin tossing example this means finding the rate function for atypical sequences of tosses rather than just for an atypical proportion. As an added benefit, it sometimes happens that computing large deviations for the higher level object is easier than for the lower level one.

Varadhan's second talk focused on the application of these principles to interacting particles systems, random walks in random environments, and stochastic Hamilton-Jacobi-Bellman equations. In a model of interacting random walks one is led naturally to study the motion of tagged particles. A nice model which has simple structure but many of the complexities of real systems is the exclusion process. Here particles are performing continuous time random walks, with the only interaction being that of exclusion – hops to already occupied sites are simply not allowed. A further simplification is to consider the case where the jump law is symmetric.

Now one scales space and time diffusively. The total density of particles will evolve on the large scale according to the heat equation, with a bulk diffusivity given by the variance of the jump law. At this level there is no sign of the interaction because the particles are indistinguishable. The probability to see some other space-time profile is given by a negative Sobolev norm of the extent to which that profile violates the heat equation. On the other hand, in equilibrium, a tagged particle converges to a Brownian motion with a different self-diffusion coefficient, because there are other particles in its way, slowing it down. The reconciliation between the two diffusion coefficients comes from seeing that in non-equilibrium the tagged particle is asymptotically a diffusion with self-diffusion as its volatility but also with a special drift chosen so that a large collection of such particles can satisfy the heat equation with the bulk diffusion coefficient.

Next one asks about the large deviation probability that the tagged particle looks like some other process. It turns out that, to compute this probability, one should match this process as closely as possible by an appropriate choice of a drift. Then the rate function

is a combination of the entropy cost and the cost of choosing this drift. The nice thing is that once again, by going to an appropriately high level, entropy reemerges.

In his final talk, Varadhan highlighted some recent joint work with Sourav Chatterjee on large deviations for random graphs and random matrices. The most famous random graph is the canonical Erdős-Renyi model: on n vertices, keep each edge of the complete graph independently with probability p . Here p is to be fixed as n becomes large. Vertex degrees thus grow like n and the random graph is said to be “dense.” (For comparison, the analogue of the percolation phase transition – the emergence of the giant component – occurs at $p \sim 1/n$.)

The typical behaviour of this graph is well-understood. One might ask about the number of triangles, or more generally about various subgraph densities; there are in fact many large deviations results for such statistics. Varadhan and Chatterjee develop a far-reaching generalization that describes the large deviations of the graph itself. Besides recovering results for all subgraph densities via contraction, they answer a deeper question: “What does an Erdős-Renyi random graph look like when a rare event happens?”

The key insight turns out to lie in choosing the right underlying space; the pioneering work here is that of Lovasz and Szegedy on limits of dense graphs. One puts all the graphs on the same space by encoding the adjacency matrix as an indicator function on the unit square, constant in each block of the $n \times n$ grid. Typically, one has weak convergence to the constant function p ; the weak topology is unsatisfactory, however, as subgraph densities are not continuous. The strong topology solves the latter problem but lacks a law of large numbers and the necessary compactness. There is a “Goldilocks topology” natural to the setting; called the cut topology; it has both the required continuity and compactness. The latter is in fact a deep result of Lovász and Szegedy whose proof involves the Szemerédi’s regularity lemma. Szemerédi’s lemma is also invoked to prove the large deviations principle.

A consequence is a fascinating double phase transition. If one observes an atypical triangle count within a certain interval around the typical one, the random graph looks like the usual one but with a modified p . Outside this interval, however, the graph does not look like an Erdős-Renyi graph at all: with a much larger triangle density the graph will look like a clique, while with a much smaller density it will look bipartite. These configurations turn out to have entropy cost lower than that associated with simply modifying p .

Varadhan concluded with an application of these ideas to more general random matrices. In this context the natural questions are about spectral statistics: How likely are you to observe eigenvalues very far away from their typical location as governed by the Wigner semicircle law?

Tom Albers (Toronto), Alex Bloemendal (Toronto), Jeremy Quastel (Toronto)

Distinguished Lecture Series: Avi Wigderson

September 14-16, 2011, Held at the Fields Institute

From September 14 to 16, for the Fall 2010 Thematic Program on *Asymptotic Geometric Analysis*, the Institute was fortunate to have as Distinguished Lecturer Avi Wigderson, a Professor of Mathematics at the Institute for Advanced Study in Princeton.

Wigderson is a widely recognized authority in the diverse and evolving field of theoretical computer science. He has received the Rolf Nevanlinna Prize 1994, the Yoram Ben-Porat Presidential Prize for Outstanding Researcher, the Conant Prize 2008, and the Gödel Prize 2009. His research interests lie principally in complexity theory, algorithms, randomness, and cryptography. In his series of lectures, he generously gave us an overview on all topics mentioned here, with a strong emphasis on how they connect to the fundamental notion of randomness.

In Wigderson's first lecture, he reviewed the basic concepts of computational complexity. He started with the important distinction between *easy* versus *hard* problems. A problem is *easy* if it can be solved by an efficient algorithm, i.e., an algorithm that runs in polynomial time (polytime). The class of all problems that can be solved in polytime is denoted by P . A problem is *hard* if there is no polytime algorithm solving it. Consider the 3-colour problem, where we want to decide if a planar map is 3-colourable. Most complexity theorists believe that 3-colour is hard since it is NP -complete. NP stands for those problems solvable in *nondeterministic polytime*; a problem in NP is NP -complete if we can efficiently reduce any NP problem to it. The famous P vs. NP question in complexity theory can then be stated as: is the 3-colour problem (or any other NP -complete problem) easy? Or informally, can *creativity* be automated?

He then discussed the power of randomness in saving time. He gave many interesting examples (e.g., generating large primes, estimating the volume of a convex body) where we have *probabilistic polytime* algorithms, but (still) no deterministic ones. Surprisingly, recent progress suggests that randomness may not be as powerful as it seems. A remarkable theorem by Impagliazzo and Wigderson shows that a reasonable assumption about computationally difficult problems (i.e., a problem computable in exponential time requiring exponential circuit size) would imply the existence of *pseudorandom* distributions, which cannot be distinguished from the uniform distribution by efficient algorithms, and thus can be used to derandomize any probabilistic polytime algorithms. He concluded the first lecture by discussing other computational settings, primarily probabilistic proof systems, where randomness is essential. He mentioned the PCP theorem, a striking result by Arora, Lund, Motwani, Safra, Sudan and Szegedy in the '90s, showing that every proof of a statement in a formal system can be efficiently converted into another proof in a special format that is verifiable with high probability by a randomized verifier that inspects only letters of that proof. In a rather different direction, instead of verifying a proof quickly, one can consider the prover's desire of having his or her proof verified without allowing the verifier to learn enough of the proof to publish it first. Strikingly, this is also possible using *zero-knowledge* proofs (under a plausible assumption, e.g., factoring integers is hard).

Wigderson's second lecture introduced the world of modern cryptography. He emphasized that the goals of modern cryptography are more than just secret communications. We want to deal with many situations where there are requirements for both privacy and resilience without trusted third parties, e.g., proving a person's identity, money transfer, public bids, playing poker on the phone, etc. It turns out that these goals can be achieved based on two main assumptions. First, every agent participating in the communication is computationally bounded (say, to polytime). Second, *one-way functions* exist; a function is *one-way* if it can be easily computed on every input, but hard to invert. He also formally defined the notion of *computational indistinguishability*, and showed how it can be used to define cryptographic protocols and pseudorandom distributions.

Before finishing the second lecture, Wigderson reviewed *zero-knowledge* proofs and demonstrated how they work through an interesting experiment, where he played the role of the prover, who wanted to convince the audience, the verifier, that he had a correct 3-colouring of a map. The key observation is that we can permute the colours around and convert any given 3-colouring into one of $3! = 6$ colourings, and for every round, the speaker would randomly shuffle the colours, and then the audience was only allowed to check one edge of the claimed 3-colourable map. Thus, eventually, the audience is convinced that the map is 3-colourable, but learned nothing about how to colour it. In the final lecture, Wigderson focused on *expander graphs*. Expander graphs are sparse d -regular graphs (for some fixed d), but highly connected. In other words, any two disjoint sets of vertices cannot be disconnected from each other without removing many edges. Expander graphs are widely used in computer science and have many applications in derandomization, circuit complexity, error correcting codes, network design, etc. Expander graphs also have many interesting applications in various areas of pure mathematics: topology, group theory, measure theory, number theory and especially graph theory. He discussed some applications in detail and then surveyed explicit algebraic and combinatorial constructions of expander graphs.

Dai Tri Man Lê (Toronto)

Distinguished Lecture Series: Cédric Villani

November 1-3, 2010, Held at the Fields Institute

The capacity crowd of 285 hushed as the lights dimmed in the Bahen Center auditorium and Fields Director Ed Bierstone and University of Toronto collaborator Robert McCann rose to introduce 2010 Fields Medallist Cédric Villani for his Public Lecture on November 2, 2010. Villani was sporting his trademark attire: tailcoat, nineteenth century floppy bowtie honouring scientific hero Ludwig Boltzmann, and custom-made tarantula broach. He cut a striking figure in Toronto even on the day following Hallowe'en; one can only imagine the impression his habitual costume made on the 3000 plus delegates who attended last August's International Congress of Mathematicians in sweltering Madras. Villani spoke on *The fate of the solar system*—his first of three talks comprising a Fields Institute Distinguished Lecture Series which aimed to expose the work on the

kinetic theory of gases which garnered Villani a Fields medal. His lecture series took place in parallel with a Fields workshop devoted to another of Villani's celebrated research themes *Geometric probability and optimal transportation*—organized by McCann and Boaz Klartag (Tel Aviv) as part of the 2010 thematic program *Asymptotic Geometric Analysis*.

In 2009, at the age of 35 and after nearly ten years as Professor at the Ecole Normale Supérieure de Lyon, Villani became the director of the Institut Henri Poincaré in Paris. After completing his Ph.D. in 1998 under the supervision of Pierre Louis Lions, he held distinguished visiting positions at the Georgia Institute of Technology, Berkeley, the Institute for Advanced Study, and the Institut des Hautes Etudes Scientifiques, following a year as Maître de Conférences at the Ecole Normale Supérieure de Paris. Lions-Villani join the tradition of academic father-son Fields medallists started by Schwartz, Grothendieck and Deligne and continued by Atiyah and Donaldson. A remarkably deep and insightful mathematician, Villani is best known for his ground breaking work in the kinetic theory of gases—particularly on thermal equilibration in the presence or absence of magnetic fields—and in optimal transportation. In recognition of these contributions, he has been honoured with a long list of prestigious awards leading up to the 2010 Fields medal. He has also written several influential books and review papers on a wide range of topics, including optimal transportation and the Boltzmann equation.

In his lecture on the fate of the solar system, Villani addressed the question of whether it is possible to predict the long term behaviour of the solar system mathematically, despite its complex and chaotic nature. This question has been studied for several centuries by both physicists and mathematicians and has led to new fields of study for both communities. Villani gave a beautiful and publicly accessible overview of the history of the problem, tracing developments from the time of Newton, Laplace and Poincaré up to the present. He touched in particular on the KAM theorem of Kolmogorov, Arnold and Moser, which asserts that most perturbations of an integrable system fail to destroy many of the hallmarks of its predictability.

The second lecture dealt with interacting particle systems and Landau damping. Villani began by reviewing the derivation of the Vlasov equation, an analogue of Newton's second law which deals with continuous matter (such as a gas or plasma) rather than discrete particles. A crucial feature of this equation is that it models conservative collisionless dynamics; therefore, the equation is time reversible and entropy remains constant rather than increasing. Intuitively, this means that no information is lost by the system as time progresses and so the initial state of the plasma can be deduced from its state at any time thereafter. In 1946, Landau argued that, for a linearized version of this equation, the force exerted on the particles by each other, decays to zero (or is damped out) as time goes to infinity. This was a very counter-intuitive result, as one cannot recover an initial state from a final state with no forces and so it seems to imply that the Vlasov equation exhibits time irreversible behaviour. It has since been argued that this linearization is a poor approximation of the full Vlasov equation for large times. In particular, entropy conservation is lost and so one should not expect information to be preserved. Numerical evidence has been contradictory and inconclusive on these points.

Villani then stated his spectacular joint result with former doctoral student Clément Mouhot: roughly speaking, even for the full (non-linearized) Vlasov equation, the force decays to zero, and furthermore, the decay happens exponentially fast. Heuristically, this apparent contradiction with the preservation of information can be resolved by noting that for large times the information is concentrated on very small velocity scales; that is, small differences in velocities at a large time can represent a large difference in the initial state and so this information gets harder to see but does not disappear entirely. In the remainder of his talk, Villani discussed some aspects of the proof of this theorem, setting the stage for his third lecture.

His final talk, *From echo analysis to nonlinear Landau damping*, was geared towards a more specialized audience and featured a hands-on blackboard sketch of the proof for the theorem articulated via the slick laptop presentation of the previous lecture. The framework for this analysis is the use of a new family of sophisticated analytic norms. These norms have a hybridized flavour; they measure the size of derivatives of the density of matter with respect to velocity variables and the size of the Fourier coefficients of the density with respect to position variables. Regularity, or smoothness, with respect to velocity is very important in this setting as it corresponds to the long time behaviour of the solution. In fact, regularity, as measured precisely by these new analytic norms, implies the decay of the force. From this perspective, then, regularity is not only crucial mathematically but it has a physical interpretation as well; it drives the Landau damping and can actually be measured experimentally. This is analogous to the way that the decay of a function corresponds to the integrability of its Fourier transform in the Riemann–Lebesgue Lemma. In addition, Villani outlined some surprising and striking parallels with KAM theory.

Cédric Villani's lecture series provided a great deal of insight into the rich and complex mathematics behind the thermal equilibration of kinetic gases. Villani is certainly a profound and creative mathematician. During his visit to the Fields institute, he proved to be an extremely engaging and inspirational speaker as well.

*Brendan Pass and
Robert McCann (Toronto)*

Distinguished Lecture Series: Shing-Tung Yau

January 19-21, 2011, Held at the Fields Institute

The 2011 Fields Institute Distinguished Lecture Series opened with one of the brightest stars in mathematics today: Shing-Tung Yau of Harvard University and the Chinese University of Hong Kong.

Yau is the world's pre-eminent geometric analyst, working at the interface between differential geometry and nonlinear partial differential equations. His numerous brilliant results, as well as the pervasive influence of his ideas on the mathematical community, have resulted in many awards, including the 1981 Veblen Prize (with Gromov), the 1982 Fields Medal (with Connes and Thurston), a 1984 MacArthur fellowship, the 1994

Crafoord Prize (with Donaldson), and most recently the 2010 Wolf prize (with Sullivan).

Yau delivered three lectures from January 19–21, 2011, the first two of which were public lectures entitled *What is the Shape of Inner Space?*—a nod to the title of his new book written with Steve Nadis, entitled *The Shape of Inner Space: String Theory and the Geometry of the Universe's Hidden Dimensions*. The first lecture was delivered to a full house in the Earth Sciences Auditorium at the University of Toronto. A wide spectrum of people were in attendance, from academics and students in the local math departments to community math enthusiasts, as well as a TV crew for the local Chinese-Canadian station.

Yau's public lectures focused on the personal history and scientific context of his famous work resolving the Calabi conjecture, which concerns the existence of Einstein metrics on Kähler manifolds. Yau's 1977 paper entitled *Calabi's conjecture and some new results in algebraic geometry* proved the conjecture and instantly established him as a leader in the field; three notable aspects of this work that may not be immediately apparent in the mathematical literature were brought out in Yau's lecture.

The first aspect emphasized by Yau was that in the 1970s geometers largely believed that Calabi's conjecture was "too good to be true." Several of today's top geometers, including Yau, expended a great deal of effort attempting to disprove the conjecture. In fact, Yau presented a lecture at a 1973 conference at Stanford, with Calabi in attendance, in which he explained what he believed to be a counterexample to the conjecture. Several months passed before errors were found; Yau described the embarrassment he felt at having been so thoroughly misled. Faced with this setback, Yau worked furiously, developing a battery of tools for understanding the behaviour of Monge-Ampère equations, and emerged in late 1975 with a proof, which he checked together with Calabi and Nirenberg on Christmas Day. In his talks Yau stressed that the seemingly wasted energy expended in producing counterexamples eventually bore fruit, becoming interesting corollaries of the solution to the Calabi conjecture, which ended up solving several outstanding problems in algebraic geometry.

The second aspect Yau discussed was that he did not work in isolation. He carefully traced the evolution of his ideas, from his attendance in an otherwise empty class taught by C. Morrey on partial differential equations, to his study of papers by Calabi and Nirenberg, to his work with Shiu-Yuen Cheng on real Monge-Ampère equations and beyond.

The third point emphasized by Yau, and perhaps the reason why his work has so captured the public imagination, is the relation to theoretical physics. Yau's work achieved a further level of prominence with the development of string theory in the 1980s as a possible route to a coherent framework incorporating quantum mechanics and general relativity. The universe itself was theorized to be a product of usual 4-dimensional space-

time with a tiny 6-dimensional Kähler-Einstein manifold with zero Ricci curvature, whose existence is guaranteed by Yau's theorem. The geometry of this space, called a Calabi-Yau manifold, was then theorized to explain aspects of our universe such as particle content, particle masses, and other fundamental physical constants.

In his final lecture, entitled Mass and Momentum in General Relativity, was delivered to an audience of specialists in the Fields Institute. Yau described his recent progress with Mu-Tao Wang (Columbia) on the long-standing problem of defining a local or quasi-local mass in general relativity. Yau explained that while it is not possible to express the total energy of the universe as the integral of a local density along a space-like hypersurface, it is still possible to have a quasi-local mass, "where a total energy-momentum four-vector is assigned to any space-like sphere bounding a compact portion of a space-like hypersurface." He proposes an interesting solution that is characterized by a list of reasonable properties and can be computed by making a non-canonical choice of local embedding into flat Minkowski space-time.

Marco Gualtieri (Toronto)

Distinguished Lecture Series: Yakov Sinai

February 22-24, 2011, Held at the Fields Institute

The Distinguished Lecture Series of the thematic program on Dynamics and Transport in Disordered Systems was given by Yakov Grigorevich Sinai. He received his Ph.D. from Moscow State University in 1960 under the supervision of A.Kolmogorov, and is one of the internationally leading experts in the theory of dynamical systems, probability theory and mathematical physics. Among his most recognized results are the formulation of the Kolmogorov-Sinai entropy, the construction of Sinai-Ruelle-Bowen measures, ergodic and statistical properties of dispersing billiards, the Pirogov-Sinai theory of phase transitions, Sinai's random walk, his works on Anderson localization and the spectral properties of Schrödinger operators.

The impact of his achievements on both mathematics and physics is also shown by his numerous awards, which include the Boltzmann Gold Medal, the Heineman Prize, the Markov Prize, the Dirac Medal, the Wolf Prize, the Moser Prize, the Frederic Esser Nemmers Prize, the Lagrange Prize, the Henri Poincaré Prize, and the Dobrushin International Prize. Currently he is a professor of mathematics at Princeton University, and principal researcher at the Landau Institute of Theoretical Physics.

The first lecture described his recent results, obtained jointly with F.Cellarosi, on the statistical properties of the Möbius function. Since the Riemann zeta function can be expressed in terms of the Möbius function, various results related to prime numbers can be related to properties of the Möbius function. The prime number theorem, for example, is equivalent to the statement that the sum of the first N values of the Möbius function grows as $o(N)$. The statement that the rate of growth of this sum is $O_\varepsilon(N^{1/2} + \varepsilon)$ is equivalent to the Riemann hypothesis. Therefore, it is important to understand the nature of the oscillations of the Möbius function. Using an analogy with statistical mechanics

Sinai showed that rewriting the inverse of the zeta function in terms of a sum over products of prime numbers suggests defining a certain sequence π_1, π_2, \dots of probability distributions on the set of square-free integers. The key feature of this construction is that powers belonging to different prime numbers in the prime number factorization are independent random variables with respect to π_m . Therefore, a weighted sum of these powers represents a sum of independent random variables. From this observation he then showed that for an appropriate choice of the weights the distribution of such sums converges to a special infinitely divisible distribution, known as the Dickman-De Bruijn distribution. This result provides information about the structure of the set of square-free integers, and hence also of the Möbius function.

In the second lecture, he explained the following problem in the the same spirit. Fix an integer N and a real number α between 0 and 1. The fractional part of the numbers n^α for integers n between 1 and N , after rescaling by N and translating by $N/2$, results in a sequence in the interval $[-N/2, N/2]$. As was explained by Sinai, it is reasonable to expect that the fraction of elements of this sequence that fall in any given interval has a limiting distribution as N tends to infinity. It was discovered by M. Boshernitzan that if $\alpha \neq 1/2$, this limit is a Poisson random field, whereas for $\alpha = 1/2$, the limiting distribution is very different. This latter case was studied by N. Elkies and C. McMullen. They found that the limiting distribution has a very interesting structure. Namely its density is constant on an interval, and is analytic on two further intervals. In this second lecture Sinai presented a different approach to show the existence of this limiting distribution for $\alpha = 1/2$. The key observation in his approach is that the sequence of the fractional parts of $n^{1/2}$ can be obtained approximately as the result of a certain rotation of the unit circle. He showed that this rotation can be obtained by an explicit calculation, which also provides the expression for the angle of rotation in terms of a continued fraction. This continued fraction representation allows one to apply a general result of Sinai and C. Ulcigrai related to renewal theory studied in probability theory, to conclude that the limiting distribution exists.

In the final lecture Sinai presented joint work with D. Li on a problem related to fluid dynamics. The starting point is the two-dimensional Navier-Stokes system. He explained how to rewrite it in terms of the stream function, and how a representation in terms of its Fourier modes provides a very efficient way to describe the Navier-Stokes dynamics. In particular, he explained how regularity properties of solutions are most conveniently expressed in this setting – an older result of a joint work with J. Mattingly. The problem addressed in this lecture was the description of a kind of bifurcation of solutions of the Navier-Stokes equation – for example the break-up of a vortex into three vortices as time evolves. Using the formulation in terms of Fourier coefficients Sinai showed that such a transition can be constructed using a perturbative analysis and an application of the implicit function theorem.

A characteristic of Sinai's scientific work is its remarkable diversity in both the subject matter and the mathematical techniques that are used and developed. And so it was hardly surprising that his series of three one-hour lectures covered problems ranging from number theory to fluid mechanics. In the lectures Sinai provided the audience with a

glimpse of how he views and uses fundamental ideas from statistical mechanics and dynamical systems to solve problems that emerge in very different areas of mathematics.
Alexander Grigo (Toronto)

OUTREACH

Fields Undergraduate Network

July 1, 2010 – June 30, 2011

The Fields Undergraduate Network was established to provide tailored research programming for undergraduates, organized by undergraduates. Compared to local and other smaller scale events, the Network served as a stage for student leaders to engage a wider undergraduate mathematics audience. For the period of July 1, 2010 – June 30, 2011, funding for all Network events came from the Fields Institute. Student transport and accommodation was typically covered by the student's home university.

As illustrated by the past year's activity, the vision of the Network is to foster a more integrated mathematics community. The immediate tasks were carried through by the Fields' staff but the vision for future events is collectively evolving. As we pass through the first series of events, we are beginning to move beyond the traditional one-day weekend workshops. We hope to see a wider variety of programming in the future.

We have fostered new connections between student groups, university departments, and other mathematical groups. This was achieved by the hosting of events on various Ontario University campuses and recognition of our achievement by the Directors of the Fields Institute. We were also fortunate that the Institute provided access to many of the key speakers at our events. Typically, these non-local speakers were participants in the Fields' flagship Thematic Programs.

In the coming year we will continue to develop partnerships established with the annual Canadian Undergraduate Mathematics Conference, the Fields-MITACS Undergraduate Summer Research Program, the Waterloo Mathematics Review, Science Rendezvous, and the MITACS Globalink Summer Programs, And some of the other associated conferences being held at the Fields Institute such as the 3C International Risk Forum.

The Network presented its coming year's events at the Fields Institute's Annual General Meeting and was recognized by numerous southern Ontario mathematics departmental chairs. At the Canadian Undergraduate Mathematics Conference 2011 at Laval University, another meeting was successfully executed establishing partnerships across Canada, from the University of British Columbia to Dalhousie University.

Our reputation has been firmly set and we are looking forward to providing more programming in the coming year.

Richard Cerezo

Math Circles

Every Saturday afternoon, from mid-September until mid-June, high school students from across the greater Toronto area converge on the Fields Institute to work on challenging math questions. It is called Fields Math Circles, and it is an extra-curricular high school enriched-level mathematics club, where students can broaden their mathematical knowledge and improve their problem-solving skills, for fun, personal interest and also to prepare for math competitions.

Principle session instructors, dan schnabel and Chris Wu, together with help from Peter Crippin, Zsuzsanna Dancso, Bram Isgur and Alexander Remorov, worked hard in the 2010-2011 Math Circles year, to deliver a rich and varied program to two groups of students – known as the Solving Group and the Advanced Solving Group.

Supported by a generous grant from Angoss Software Corporation, Fields Math Circles was able to send eighteen students, to the annual Math Challenge Team Invitational Competition (MCTIC), held at the University of Waterloo in May 2011. For many of the students, this was the highlight of the Math Circles year.

MCTIC is a full day of competition, with nine-person teams competing in five events, followed by a banquet dinner. Nineteen teams from across Ontario participated. The Fields Math Circles teams were known as Toronto-A and Toronto-AA, the latter composed mostly of veterans from MCTIC 2010.

The Toronto-A team placed 10th, putting them in the middle of the pack. Their coach, Chris Wu, was pleased with this result as many of the students on the team were drawn from the Solving Group and are young enough that they will be returning as veterans in future MCTIC competitions.

The Toronto-AA team scored 301 out of a possible 351 points to take 2nd place. At the end of the day, when score summaries were made available, they showed that the Toronto-AA team was in first place right until the last of the day's events. Coach dan schnabel noted that, since the focus of Math Circles is more about learning than competing, second place is an impressive result. "Although some teams trained at great length, specifically for this day, we just came to have fun."

Particularly noteworthy was the performance of Fields Math Circles' Dani Spivak. He was the only one of the 171 competitors to achieve a perfect score on both the individual questions event and the mental math event. The individual questions event included questions such as the following:

The number $1764622B5362A6$ is divisible by 792. A and B represent digits. Determine the sum $A + B$.

This was just the third question out of eight in that event.

Fields Math Circles provides mathematically talented high school students with

interesting math challenges outside of their regular school experience and delivers these in an environment in which mathematics is a fun, friendly, social activity.

dan schnabel

Math Performance Festival, Windows into Elementary Mathematics, and Joy of X
Organized by George Gadanidis (Western)

The Math Performance Festival completed its fourth year, with 75 entries from Canada and Brazil. We are happy to announce that Brazilian mathematician/philosopher Ubi D'Ambrosio has joined the panel of celebrity judges. The entries selected by the judges will be announced early in October. The Festival has also added a Science category.

The Math Performance Festival offers students of all ages an opportunity to think creatively about mathematics and to share their ideas with the wider world. Below is a grade 3/4 class performing their song, "More Homework Like This". Students found pairs of numbers that fit number sentences like $_ + _ = 10$ and $_ + _ < 10$, and plotted the pairs on a coordinate grid. They shared their learning with parents and feedback from parents was used to create the lyrics for their song.

The Windows into Elementary Mathematics project invites Canadian mathematicians to share their thinking about elementary math topics. The latest mathematician to be interviewed is Brett Stevens of Carleton University, on the topic of *Latin Squares, Sudoku & better crops*. Steven's interview includes a music video called *Math Grows*, based on his interview clips where he shares that sometimes math grows as a result of solving real life problems and other times for the pure joy of it.

The Fields Institute funds Joy of X musical performances for Ontario elementary schools. The songs performed are written using students writing and shared thinking while working on big ideas of mathematics (such as infinity and limit in grade 3). These classroom-based songs are then shared with other school through the concerts. All students receive a booklet containing the songs as well as extension activities. In 2010-2011, four concerts were performed in London and six in the greater Toronto area, for over 4,000 students.

George Gadanidis (Western)

Caribou Mathematics Competition at Brock
Organized by Thomas Wolf (Brock)

The Caribou Contest has had many positive effects at participating schools so far, and we expect these positive impacts to be reproduced at other schools as the reach of the contests grows. In participating elementary schools, feedback from teachers has noted that students' understanding of mathematics has become richer, as they demonstrate a greater facility with problem solving, patterns, symmetries, and logic. But most importantly, and beyond any content knowledge, students' image of mathematics has

changed: they now look upon mathematics as something cool to compete in and to be good at. This image-building is expected to have a profound long-term effect.

The most direct effect of the contests is, of course, the additional exercise that students get. With six contests per year in each age group, and practice at home and in new math clubs, students improve their abilities, and with improved abilities comes greater interest.

Currently the number of practice tests taken is about 2.5 times higher than the number of contests taken; this speaks to the effectiveness of the contest in stimulating regular students practice. It will be interesting to watch how this ratio changes over the years. We expect it to grow.

Within five years, elementary-school students who have been participating in Caribou Contests in 2009/10, will be at high school and old enough to participate in international mathematics olympiads. Within a few years after that, they will apply to study at colleges and universities. We are confident that the impact of the Caribou Contests will be visible in statistics on applications for math/science/technology studies in Canada.

GENERAL SCIENTIFIC ACTIVITIES

Joint Fields-Perimeter Institute Workshop on Random Matrix Techniques in Quantum Information Theory

July 4-6, 2010, Held at the Perimeter Institute

Organizers: Patrick Hayden (Perimeter/McGill), Benoit Collins (Ottawa), Ion Nechita (Ottawa)

The Fields-Perimeter joint workshop on Random Matrix Techniques in Quantum Information Theory was held at the Perimeter Institute from July 4-6, 2010. It was organized jointly by Benoît Collins (Ottawa), Patrick Hayden (McGill/Perimeter) and Ion Nechita (Ottawa).

The aim of this workshop was to bring together researchers from the areas of probability theory and random matrix theory in mathematics with specialists from quantum information theory. Over the last decade it was discovered that in order to tackle important questions in quantum information theory, such as additivity problems, and probabilistic methods, random matrix methods could be of crucial help.

A deeper level of interaction between the quantum information theory community and mathematics had already been recognized as fundamental, and joint events were organized with the operator algebra and operator space communities. However, bringing together mathematicians working in probability theory and quantum information theorists with an interest in statistical methods had not yet been accomplished, and we believe that our workshop quite efficiently filled that gap.

It was important to bring together people from probability and random matrices with those from quantum information, as huge breakthroughs have been achieved over the last few years concerning the additivity of the minimum output entropy, especially by Matthew B. Hastings (Microsoft), Hayden, and Andreas Winter (Bristol).

The motivation for the workshop was the recent resolution of quantum information theory's best-known conjecture using random matrix techniques. Updates on further developments surrounding this additivity conjecture provided some of the highlights of the workshop. The additivity conjecture was first stated by Christopher King (Northeastern) and Mary Beth Ruskai (Tufts), who were both present at the workshop. After several classes of channels were shown to satisfy the conjecture, Hayden and Winter showed that a stronger version of it, widely believed to hold at the time, was false. They used a random construction and their proof relied on concentration of measure techniques, developed earlier in joint work with Debbie Leung (Waterloo), also a workshop participant. The counterexample for the original conjecture was constructed by Hastings in 2009, his proof also relying on random matrix techniques. Talks on this subject occupied a whole day of the schedule. King and Motohisa Fukuda (UC Davis) gave an introduction to the conjecture and Hastings' proof. Fernando Brandao (UFMG) presented an alternative approach to the problem, using concentration of measure techniques. Stanislaw Szarek (Paris 6) spoke about very recent joint work of his, Guillaume Aubrun's (Camille Jordan) and Elisabeth Werner's (Case Western Reserve) on another proof of the Hastings result using Dvoretzky's theorem. Collins introduced free probability techniques, helpful in studying random quantum channels that can be used to give precise results on the minimal output entropies. Finally, the Additivity Problem Day was concluded by Aram Harrow's (Bristol) talk on the computational complexity of approximating entropies of channels. This session was emblematic of the workshop, with mathematicians and quantum theorists alternating on the podium, presenting their research to a large audience.

The workshop was attended by over 40 participants, including more than a dozen students. Twenty lectures were delivered. As the audience members' backgrounds were extremely diverse, every speaker split their talk into two parts. The first half had to be completely accessible to the other community, and the second addressed research questions relevant to the conference. For the mathematicians, this was a unique chance to learn firsthand about the quantum information techniques and important problems. For the quantum information community, it was a unique opportunity to learn about recent and more classical techniques in random matrix theory.

Time was set aside to allow for discussions between the participants. In particular, there was a problem session that gave rise to many new and interesting questions, providing material for future research work. Audience members participated enthusiastically in these sessions, offering problems, suggestions and even making a start on some solutions. This collaboration between the Fields Institute and the Perimeter Institute enjoyed national media coverage when Canadian Prime Minister Stephen Harper unexpectedly invited himself to our conference. He took this occasion to greet Stephen Hawking (who was visiting the PI at the time) and to make an important announcement about the

funding of postdoctoral fellowships in Canada, as well as to share Ontario wine with the participants.

The workshop was very timely, and the organizers hope it will prove to be a first milestone on the road towards a fruitful and intensive collaboration between the two communities.

Benoît Collins (Ottawa)

Conference in Iwasawa Theory

July 5-9, 2010, Held at the Fields Institute

Organizing Committee: Manfred Kolster (McMaster), Cristian D. Popescu (UCSD), Romyar Sharifi (Arizona).

This was the fourth conference in a biannual series, following meetings in Besançon (France), Limoges (France) and Irsee (Germany), which were preceded by a pre-inaugural meeting in Caen (France) in 2002. The conference brought together senior researchers, post-doctoral fellows and graduate students working in areas of mathematics closely related to Iwasawa Theory. The conference was supported by the Fields Institute and the NSF Award DMS-1005225.

Number Theory is one of the oldest and most active areas of mathematics research. One of the central research themes in number theory is the study of sets of solutions of polynomial equations with integral coefficients. A famous example in this direction is Fermat's equation

$$X^n + Y^n = Z^n$$

where n is an integer strictly larger than 2. In 1637, it was conjectured by the French lawyer and amateur mathematician Pierre de Fermat that the equation above has no integral solutions (X, Y, Z) such that $XYZ \neq 0$. This conjecture was proved in the affirmative in 1995 by Andrew Wiles of Princeton University and his collaborator, Richard Taylor, after a tour de force involving most of the number theoretic techniques developed during the past three and a half centuries.

Iwasawa Theory is a relatively new and extremely active area of research of number theory, founded in the 1950s by the Japanese-born mathematician Kenkichi Iwasawa of Princeton University. The main idea in Iwasawa theory is that certain number-theoretic objects of central importance (e.g. ideal class groups or, more generally, Selmer groups) are easier to study in infinite sequences along so called Iwasawa towers of number fields rather than individually. Over the years, this idea has proved very fruitful and has led to much progress in number theory. The celebrated Wiles-Taylor proof of Fermat's Conjecture uses many Iwasawa-theoretic results and techniques in an essential way. Nevertheless, Iwasawa theory remains riddled with very deep and far reaching open questions and conjectures. A large number of number theorists around the world are actively investigating and constantly making progress towards the solution of these conjectures.

The main goal of the Iwasawa Conference Series is to bring together the most active researchers in this area on a biannual basis in order to discuss, over a period of 4-5 days, the progress made in the field to date. The organizing and scientific committees of these meetings make special efforts to fund the participation of younger mathematicians (post-doctoral fellows and graduate students) as well. At the 2010 meeting at the Fields Institute, there were 19 exciting one hour talks, followed by stimulating question and discussion sessions. Several exciting new results were announced. Among these were the Ritter-Weiss proof of an Equivariant Main Conjecture in Iwasawa Theory and the Greither-Popescu proof of an Equivariant Main Conjecture via their theory of abstract 1-motives, with applications to proofs of the Brumer-Stark and Coates-Sinnott Conjectures.

Canadian Undergraduate Mathematics Conference 2010

July 6-10, 2010, Held at the University of Waterloo

Organizers: Richard Zsolt and Nathan Yeung

The CUMC is a unique academic event in North America. Now in its eighteenth year, the conference is the principal opportunity for enthusiastic undergraduates to converge and share their passion for mathematics. No other non-competitive mathematics event has annually attracted students from across the continent in such numbers, to share in teaching, learning and discussion. The conference aims to provide a wide range of valuable experience to aspiring mathematicians. Traveling to a Canadian university with a strong mathematics program, students sample the university life away from their own campus. At each year's hosting school, the students meet with like-minded peers, learning of the interest in mathematics that exists throughout Canada, previously only known to them at their home institution. Students practice their expository skills and share novel mathematics through student-run lectures, an invaluable skill normally not present in an undergraduate mathematics curriculum. Finally, free food and keynote speakers give the event an official flavour and ensure an overall fun and enriching experience.

CUMC 2010 marked the return of the conference to the University of Waterloo (UW) for the first time in a decade. As this year's organizing team, we wished to have the CUMC be representative of the changes we have experienced at UW and have the conference be a vehicle for sharing the pride and excitement for mathematics present among students in our faculty. In particular, we wanted our event to reflect the growth of the faculty, in both size of the student body and the diversity of programs available at UW. In previous years, the CUMC has attracted 100-150 students per year. This year's event, CUMC 2010, had over 245 attendees, with approximately 160 students making the trip from their home institution to Waterloo. Furthermore, the conference showed an expansion in subject matter available to conference goers. This year students in fields such as financial mathematics and bioinformatics, in addition to the normal crowd of students from pure mathematics, applied mathematics, computer science, statistics and physics, also attended. Of the 245 participating students, we are particularly proud of the 100 students who decided to give student talks. Besides recording breaking attendance, we also apologize

for the recording breaking heat wave that our conference goers survived while in attendance.

This year's event would not have been possible without the support of many people. Our eight keynote speakers generously donated their time to travel and give a wide range of talks. Our own mathematics faculty and administrative staff worked tirelessly with us to make sure that the conference went smoothly. Our Dean of Mathematics, Ian Goulden, displayed a particular zest when encouraging and nurturing the CUMC, offering support and coordinating departmental events coinciding with the conference, such as UW's Combinatorics Summer School. Finally, our generous sponsors, both public and private, ensured that our student-run event could remain affordable for the students who made the trip to the University of Waterloo this last year.

Schubert Calculus Workshop and Summer School

July 7-10 and July 12-15, 2010, Held at the Fields Institute

Organizers: Anne Schilling (UC Davis), Mike Zabrocki (York)

Mathematicians working in the fields of geometry, algebraic combinatorics and mathematical physics met at the Fields Institute and the University of Toronto campus this July for a summer school and workshop on the topic of Affine Schubert Calculus. The first four days of this event consisted of expository lectures, and then another four days of talks highlighting recent research in this area. This meeting was the closing event associated to a NSF Focused Research Group (FRG) grant where the members' research was concentrated on mathematics related to this subject.

Schubert calculus refers to manipulations of subsets of Grassmann varieties called Schubert cells. Schur functions are an algebraic realization of the cohomology classes of the Grassmannians. The title of the workshop and summer school, 'Affine Schubert Calculus,' refers to an extension of Schubert calculus to affine Grassmannians. The algebraic realization corresponding to Schur functions are the k -Schur functions of Lapointe-Lascoux and Morse (where the ' k ' here represents an affine grading). k -Schur functions were first discovered because of their relationship to Macdonald symmetric functions. Later, Thomas Lam showed that the k -Schur functions were connected to the geometry and topology of the affine Grassmannian.

One of the motivating open problems of this subject is to understand the algebra of k -Schur functions well enough to develop a combinatorial model of the structure constants. It is known that the Gromov-Witten invariants appear as special cases of the structure constants of the k -Schur functions and so answering this particular aspect of the affine Schubert calculus would help answer long standing open problems in the area of mathematical physics and geometry.

The summer school opened with a talk by Jennifer Morse (Drexel) who, in the first of three presentations, gave an explanation of Schur symmetric functions and the Pieri rule that she generalized in later talks. She showed in her second and third talks how

changing one element of the definition of Schur functions gives a definition of k -Schur functions and changing it in a different way gives a definition of dual k -Schur functions.

Her three lectures gave background that was used in the presentations by Luc Lapointe (University of Talca). In the first lecture he told the story about how the k -Schur functions were originally discovered as the 'largest' basis of a subspace of Macdonald's symmetric functions for which the Macdonald symmetric functions were positive. In the second lecture he outlined a list of properties, conjectures and open problems.

Thomas Lam (University of Michigan) gave a series of lectures for which he had produced lecture notes in advance of the summer school covering a very useful array of mathematics for algebraic combinatorics. He showed the definition of Stanley symmetric functions which are a generating function for the reduced words of a permutation and then generalized them to affine Stanley symmetric functions and showed how they were related to k -Schur functions.

A portion of the FRG grant was dedicated to computational aspects of affine Schubert calculus. Jason Bandlow (University of Pennsylvania) and Nicolas Thiery (Universite Paris Sud II) gave a number of tutorials on the open source mathematics software Sage which has programs to compute with k -Schur functions and an extensive algebraic combinatorics toolbox. Mark Shimozono (Virginia Tech) gave a series of lectures laying out an explicit method for computing affine Stanley symmetric functions for all types and made connections between the geometry and the algebra in detail. Lenny Tevlin (New York University) gave an introductory lecture on the last day of the summer school event on quasi-symmetric functions.

Participants had a day off and the workshop portion of the event was held in the following four days. It was a really pleasant experience to hold this event at this time of the year since the summer is, in my opinion, the best time of year to visit Toronto. We had a beautiful day on the free day between the summer school and workshop parts of the event and a few of the participants took the ferry to see the islands.

The topics of the workshop were more focused on recent research results and the talks opened with a presentation by Sami Assaf (MIT). She spoke about joint work with Sara Billey that showed the k -Schur functions were Schur positive. Jason Bandlow (University of Pennsylvania) spoke about joint work that he did with myself and Anne Schilling on the Murnaghan-Nakayama rule for k -Schur function which gives an expansion of k -Schur functions in the power sum generators of the algebra. Jonah Blasiak (University of Chicago) spoke about the representation theory of graded S_n modules which are conjectured to have a decomposition into S_n representations given by k -Schur functions.

Some of the talks were about constructions which were on problems that were analogous research in Affine Schubert Calculus and others were on closely related topics like crystals and quantum Schubert calculus. Hugh Thomas (University of New Brunswick) gave an interesting talk about how to derive Littlewood-Richardson rules using Pieri rules

and jeu-de-taquin. Luis Serrano (University of Michigan) spoke on work to generalize non-commutative Schur functions of the methods of Fomin and Greene to other types. Thomas Lam had used similar techniques to define non-commutative k -Schur functions.

Mike Zabrocki (York)

Workshop on Groups and Group Actions in Operator Theory

The workshop took place at the University of Ottawa from July 12–16, 2010. It was the first in a series of joint events between the mathematics departments of the Universidade Federal de Santa Catarina, Florianópolis, Brazil, and the University of Ottawa, and was the result of a recent agreement between the two universities, initiated by the Mathematics departments. The workshop was open to everybody, and the majority of speakers and participants came from outside of the two signatory Universities.

Operator algebras originated in the work of John von Neumann (in particular in his search for a natural mathematical framework for quantum mechanics), Isreal Gelfand and Mark Naïmark. Von Neumann algebras incorporate the noncommutative versions of measure theory, topology and differential geometry. The theory of operator algebras is undoubtedly one of the domains in mathematics most notable for the depth of its problems, the richness of its ideas, its connections to many different fields, and its great potential as a unifying language and source of illumination.

This area is recognized as being among a few major fields of research strength of both the Canadian and Brazilian schools of mathematics. There is an internationally recognized research group in operator algebras in Canada and a strong subgroup in Ottawa. The department of mathematics of the Universidade Federal de Santa Catarina is building a large group of researchers in operator algebras, led by Ruy Exel (UFSC).

The workshop consisted of two three-hour minicourses, as well as a number of one-hour and 45-minute invited talks. The first mini-course was given by Vadim Kaimanovich, who was recently appointed as a Canada Research Chair Tier I at the University of Ottawa. Kaimanovich's course, entitled *Markov Chains and Groupoids*, was devoted to various probabilistic models generalizing random walks on groups (random walks in random environment and with internal degrees of freedom, along classes of equivalence relations etc.).

Main attention was paid to the problem of triviality of the Poisson boundary for invariant Markov operators and its application to amenability of groupoids. The second minicourse, entitled *Cartan Subalgebras, Fell Bundles and Twisted Actions of Inverse Semigroups*, was given by Exel. The course focused on the rich interplay between C^* -algebras and dynamical systems, beginning with the seminal work of Jean Renault (Orléans) on groupoid C^* -algebras and the description of Cartan subalgebras in terms of twisted étale groupoids and the non-commutative generalization obtained by the speaker using Fell bundles over inverse semigroups.

Invited lectures were given by Alcides Buss (UFSC), Benoît Collins (Ottawa), George

Elliott (Toronto), Ilijas Farah (York), Daniel Gonçalves (UFSC), David Kerr (Texas A&M), Ion Nechita (Ottawa), Volodymyr Nekrashevych (Texas A&M), Matthias Neufang (Carleton/Fields), Ping Wong Ng (Louisiana), Zhuang Niu (Memorial), Catalin Rada (Ottawa), Renault, and Benjamin Steinberg (Carleton).

A special afternoon session was dedicated to David Handelman (Ottawa) on the occasion of his forthcoming 60th birthday. Many animated mathematical discussions took place. New research collaborations are certainly expected to result from this event, and a conference sequel (Brazilian Operator Algebra Symposium) will be held in Florianópolis from January 31 to February 4, 2011.

Thierry Giordano and Vladimir Pestov (Ottawa)

Fields Institute-Carleton Finite Fields Workshop

July 20-23, 2010, Held at Carleton University

Organizers: Daniel Panario, David Thomson and Qiang Wang (Carleton University)

This workshop was intended to partially supplement the larger series of conferences, *Finite Fields and their Applications*, which are held in odd-numbered years. It focused on three areas of finite fields research: pseudo-random sequences, irreducible and primitive polynomials, and special functions over finite fields. All three topics have applications to digital communications, including coding theory and cryptography.

The spirit of the workshop the promotion of collaboration between finite fields researchers, and the fostering of new and innovative ideas in each area of research. The workshop attracted 35 participants, of which 17 were students and post-docs from Canada, Iran, Ireland and Singapore. In addition to 12 talks by eight invited speakers, there were eight contributed talks, mostly by graduate students, on current research.

Invited lectures and mini-courses were given by Stephen D. Cohen (Glasgow), Theo Garefalakis (Crete), Guang Gong (Waterloo), Gary McGuire (UCD Dublin), Gary Mullen (Penn State), Arne Winterhof (Austrian Academy of Sciences), Qing Xiang (Delaware) and Joe Yucas (South Illinois Carbondale). Speakers presented talks and mini-courses which outlined the current state-of-the art in each of these topics and provided open problems and new avenues of research in each talk.

Arne Winterhof presented a three-part mini-course on research methods for pseudo-random sequences. The methods presented included the computation of linear complexities and the evaluation of special exponential sums and measures of randomness. In addition, Guang Gong introduced some new constructions of pseudo-random sequences.

Gary Mullen opened the mini-course on primitive and irreducible polynomials with a survey of the state of the art. Stephen Cohen followed with an exposition of the main techniques in the area, which center around character sums and a new p -adic method. In

addition to the mini-course, Theo Garefalakis presented new results on self-reciprocal irreducible polynomials given some prescribed coefficients over finite fields.

Highly nonlinear functions over finite fields are necessary in the implementation and analysis of modern cryptosystems. Gary Mullen gave a survey of basic results on permutation polynomials and value sets of polynomials over finite fields. Gary McGuire gave an in-depth analysis of various nonlinearity properties of functions over finite fields, and their relations with cryptography and coding theory. Qing Xiang examined the relationship between highly nonlinear functions and special types of graphs. Joe Yucas presented a generalization of the so-called Dickson polynomials of the first and second kind to any positive k kind, and outlined some research avenues for the classical Dickson polynomials.

Daniel Panario

Workshop on Hybrid Dynamic Systems

July 29-31, 2010, Held at the University of Waterloo

Organizers: X. Liu (Chair, Waterloo), S. X. Shen (Waterloo), W.-C. Xie (Waterloo), M. Alwan (Waterloo), J. Liu (Waterloo), P. Stechlinski (Waterloo), H. Zhang (Waterloo), Z. Zhang (Hubei University of Economics, Wuhan, China)

Sponsored by the Fields Institute and the University of Waterloo, this workshop brought together experts, scholars, and industry members in a three-day event to discuss recent developments and results, to provide an overview of the current research and applications, and to foster collaboration among researchers.

A hybrid system is a dynamic system that exhibits both continuous and discrete dynamic behaviour. Such systems arise in a variety of applications in various industrial and technological areas such as communications, complex networks, biotechnology, artificial intelligence, switching circuits in power electronics, spacecrafts control, and ecosystems management. The interaction of continuous- and discrete-time dynamics in a hybrid system often leads to very rich dynamical behaviour and phenomena that are not encountered in purely continuous- or discrete-time systems. Due to their many important applications, hybrid systems is currently becoming a large and growing interdisciplinary area of research.

Twenty-six talks were given over the course of the workshop, with invited and contributing speakers from Canada, the United States, China, Turkey, France and Germany. The subjects of the lectures ranged from stability and control of a particular and important type of hybrid systems, called switched systems, to verification, approximation, bifurcation, sensitivity analysis, and viable attainability of general hybrid systems. Topics on stochastic hybrid systems and hybrid time-delay systems are also covered. Application topics discussed included epidemic dynamics, population models,

multi-vehicle coordination, fault estimation, chaotic attractors, and synchronization of complex networks, among many others.

The first day the workshop began with Andrew Teel of the University of California at Santa Barbara. Teel delivered a two-hour lecture on Nonlinear Stability Theory Extended to Hybrid Systems. His lecture presented a systematic framework, developed by him and his collaborators, within which the classical nonlinear stability theory pertaining to Lyapunov functions, invariance principles, linearization, singular perturbations, averaging, and cascades can be extended to hybrid systems. The robustness issue was clarified and ensuing stability theory results were outlined and illustrated with examples. The afternoon session of the first day focused on stability and switched systems; various invited and contributing speakers presented and discussed their research findings, as well as their perspectives on switched systems.

M. A. Aziz-Alaoui of the University of Le Havre in France opened the second day of talks with a presentation about networks of oscillatory dynamical systems. He first discussed complexity and how complex systems can give rise to emergent properties \tilde{n} in particular, thought arising from the neural networks in the brain \tilde{n} then elaborated upon results on complex and burst synchronization in those networks. As the study of networks pervades all areas of science, hybrid systems also find important applications in networked systems with switching topologies and impulsive communications. In the same morning session, Paul I. Barton from M.I.T. presented a lecture on Some New Results on Sensitivity Analysis of Hybrid Systems, and Sayan Mitra from the University of Illinois at Urbana Champaign spoke on Verification of Hybrid Systems through Abstractions and Approximations. The afternoon session of the second day covered diverse topics related to hybrid dynamics, including reach control of simplices, harvesting and testing of population dynamics, optimization problems with arcs of bounded variation, error diffusion algorithms, switching population models, and chaotic and hyperchaotic attractors.

The final day of the workshop started with Nasir Uddin Ahmed from the University of Ottawa. Ahmed discussing the use of operator-valued measures as feedback control for infinite-dimensional stochastic systems, stressing the importance of measure-theoretical methods in partially observed stochastic control problem with structural controls which are operator valued measures. S. Sathanathan from Tennessee State University discussed Stochastic Discrete-Time Systems under Markovian Switching, an important type of stochastic hybrid system. Marat Akhmet from Middle East Technical University in Turkey introduced Differential Equations with Piecewise Constant Argument of Generalized Type. The workshop closed after two more talks, one on bifurcation of a 3-dimensional hybrid system, and the other on stability of hybrid singularly perturbed systems with time delay.

In addition to presenting their own research findings in the field, the speakers often also provided, either in their lectures or during discussions afterwards, their opinions and insights on how they defined the field, what they thought were critical perspectives for newcomers, such as Ph.D. students and new postdocs, to the field of hybrid systems,

what they thought were ideal types of training, and what they would consider as promising new directions. Therefore, the workshop provided an excellent opportunity for graduate students to learn about new developments as well as to present their research findings.

The workshop experience was further enhanced by a banquet at the University of Waterloo on the Friday evening of July 30, as well as social time during dinners, lunches, and coffee breaks. Speakers and attendees took advantage of these times to discuss the talks and results and to connect with their fellow researchers and to seek possible collaboration for the future.

The workshop saw a total of about 50 participants, including about 20 graduate student and postdoc attendees. Several participants wrote back after the workshop saying that they found the lectures and discussions delightful and invaluable, and the experiences enjoyable.

22nd International Conference on Formal Power Series and Algebraic Combinatorics (FPSAC 2010)

August 2-6, 2010, Held at San Francisco State University

Organizers: Federico Ardila (San Francisco State University, co-chair) , Matthias Beck (San Francisco State University, co-chair), Nantel Bergeron (York University), Thomas Bliem (San Francisco State University and Universität zu Köln) , Tristram Bogart (San Francisco State University and Queen's University), Serkan Hosten (San Francisco State University), Brant Jones (University of California, Davis), Fu Liu (University of California, Davis), Peter McNamara (Bucknell University), Ellen Veomett (California State University, East Bay), Mike Zabrocki (York University)

This was the twenty-fourth conference in a series which brings together researchers from various areas of combinatorics and theoretical computer science and links them with leading scientists from allied disciplines in pure and applied mathematics, bioinformatics and physics.

FPSAC conferences feature eight to ten plenary lectures by senior researchers and scientists in the early stages of their career. These lectures are coupled with a limited number of contributed talks, providing an opportunity for both senior and junior researchers to gain exposure for their results and ideas. In addition, the conferences include problem and poster sessions as well as segments reserved for research collaboration and interactions. There were 210 registered participants from universities and research laboratories in Canada and the United States and abroad at the conference. There were 118 submissions for contributed talks and posters. 27 were accepted for talks, 56 for posters.

One of the main goals of this conference is to give researchers the opportunity to establish international contacts. This goal is particularly relevant for junior researchers and graduate students, who receive special support. Given the travel costs associated with these visits, funds were provided to support graduate students, early career researchers,

and researchers from underrepresented groups. The 2010 conference in San Francisco was supported financially by the U.S. National Science Foundation, the U.S. National Security Agency, Elsevier Publishers, San Francisco State University, and Lindo Systems. We acknowledge the Fields Institute's support with the registration process and initial accounting. In particular, we thank Nantel Bergeron for being our point of contact with the FPSAC Permanent Committee and the Fields Institute, and for providing very helpful advice during the organizing stages of the conference.

Prior to both of the conferences, many steps were taken to promote the conference, including maintaining an informative website, mailing posters to approximately one hundred universities, and emailing several hundred scientists. Consequently, there were a record number of participants from all over the world, from varied disciplines, and from both academic institutions and industry at each of the conferences. Efforts to increase the number of scientists from underrepresented groups led to the participation of an extremely high number of women and of scientists from developing countries.

Eighty-two participants were funded by an NSA grant and an NSF grant. Fifty-four were grad students, twenty were post-docs, seven were assistant professors, and one an associate professor.

Canadian Conference on Computational Geometry

August 9–11, Held at the University of Manitoba

Organizers: Helen Cameron (University of Manitoba), Stephane Durocher (co-chair) (University of Manitoba), Mark Keil (University of Saskatchewan), Andrea Mantler (University of Manitoba), Jason Morrison (co-chair) (University of Manitoba)

This was the 22nd instance of the Canadian Conference on Computational Geometry, which has been held annually at various locations in Canada since 1989. As detailed below, paper submissions and conference attendance were both high, and we received extensive positive feedback during and following the conference.

The conference on Computational Geometry began with a reception to welcome participants on the evening of the August 8, and a conference banquet was held on the evening of August 10, 2010, at the Inn at the Forks, in Winnipeg. During the conference, two parallel presentation sessions were held in the Engineering and Information Technology Complex.

This conference is a forum to disseminate and discuss theoretical and applied results in discrete and computational geometry. Computational geometry is concerned with the design of efficient algorithms, the development of software, and the study of the mathematical foundations of computational problems whose formulation involves geometric constraints. The conference format was its usual format with 2 parallel sessions and twenty minutes per talk. Three one-hour plenary talks were given, one each day, for which there was no concurrent session. A total of 66 papers were also presented

(see Table 1 for a breakdown). Submitted papers were refereed and accepted if they presented new, original, and correct results of interest to the greater computational geometry community. Accepted papers were published in the conference proceedings (both print and electronic versions) and exceptional papers were invited to be submitted to a special issue of the journal *Computational Geometry: Theory and Applications*.

The conference included three invited plenary lectures. The keynote lecture was the annual Erdos Memorial Lecture, which in 2010 was delivered by David Avis (McGill University). This lecture is held annually in memory of Paul Erdos who opened the first Canadian Conference on Computational Geometry in 1989. We also invited David Eppstein (University of California, Irvine) and David Kirkpatrick (University of British Columbia) to give the two other plenary lectures.

The measurable outcomes of the conference are two-fold: A special edition of *Computational Geometry - Theory and Application*, a survey of the conference participants' impressions has been taken and a review of the conference appeared in <http://ieonline.typepad.com/reviews/2010/08/reviewers-report-cccg-2010.html>

Workshop on Fluid Motion Driven by Immersed Structures

August 9-13, 2010, Held at the University of Toronto

Organizers: Huaxiong Huang (York), Anita Layton (Duke), Zhilin Li (North Carolina State), John Stockie (Simon Fraser)

This workshop involved 80 participants, including undergraduate students, graduate students and postdocs. The theme was the development and application of advanced computational techniques for simulating the motion of an incompressible fluid driven by flexible immersed structures. There is tremendous interest in this field, owing in large part to the multitude of applications in physiology and biology.

The workshop included two tutorials targeted at graduate students and junior mathematicians, with the goal of providing training opportunities for young scientists. The first tutorial was given by Ming-Chih Lai (National Chiao Tung University) who gave an introduction to the immersed boundary method, a numerical method for computing solutions to fluid-structure interaction problems without using a conforming mesh. The second tutorial was given by Anita Layton who gave an introduction to the immersed interface method that can be used to solve the same type of fluid-structure interaction problem as the immersed boundary method, but with better accuracy.

The workshop featured keynote lectures given by Lisa Fauci (Tulane University), Zhilin Li, John Lowengrub (University of California at Irvine), John Dolbow (Duke University), and Sheldon Wang (Midwestern State University). Fauci discussed recent insights into swimming and pumping using an immersed boundary framework. Li presented the augmented immersed interface method and described its application to free boundary and moving interface problems. Lowengrub presented his work on computing the dynamics

of multicomponent vesicles in the viscous fluid. Dolbow presented a survey on the recent advances in embedded finite element methods. Wang, fittingly on the last day of the workshop, discussed current challenges of immersed methods.

The workshop also included presentations on the development of numerical methods and their applications, by both established and junior mathematicians. Presentations on the first day focused on recent advances in various versions of the immersed boundary method. Presentations on the second day focused on development and application of the immersed interface method and related methods. The remainder of the presentations included the contact line problem, multi-phase flow, and a number of applications of the immersed boundary and related methods (jellyfish, bleb formation, biofilm, etc.).

Additionally, a poster session was held during the lunch break on the third day. There were twenty poster presentations, on novel methods for solving fluid-structure interaction problems, and on the applications of those methods.

Selected papers on topics related to the workshop will be published in a special issue of Communications in Computational Physics.

The organizers consider the workshop to have been a resounding success. The program was distinguished by its mix of speakers from departments of mathematics, engineering and other application areas. Fluid-structure interaction problems are so interdisciplinary in nature that interdisciplinary collaborations are necessary for the field to flourish. It is indeed the hope of the organizers that this workshop will spark new collaborations that in turn lead to growth in this exciting field of research.

Workshop on Selected Areas in Cryptography

August 12-13, 2010, Held at the University of Waterloo

Organizers: Alex Biryukov (Luxembourg), Guang Gong and Douglas Stinson (Waterloo)

Now in its 17th year, SAC has established itself as the premier forum for information, discussion and exchange of ideas in the area of cryptography. With about 80 in attendance, participants of this year's workshop included mathematicians and theoretical and practical cryptographers from 16 countries.

The specific areas of concentration were:

- design and analysis of symmetric key primitives and cryptosystems including block and stream ciphers, hash functions and MAC algorithms
- efficient implementations of symmetric and public key algorithms
- mathematical and algorithmic aspects of applied cryptology
- applications of coding theory and combinatorics in cryptography

The invited speakers were Keith Martin from Royal Holloway, University of London and Alexandra Boldyreva from the Georgia Institute of Technology. Martin's talk was entitled *The rise and fall and rise of combinatorial key predistribution*; it revisited some early combinatorial key predistribution schemes, discussed their limitations and identified potential areas for further research. Boldyreva's lecture was entitled *Search on encrypted data in the symmetric-key setting*. It summarized the existing solutions for the problem of searchable encryption in the symmetric-key setting and discussed various tradeoffs between functionality, efficiency and security. Both talks gave participants a wide perspective of two important research areas.

There were also 24 contributed talks on recent research progress in areas including hash functions, stream ciphers, efficient implementations, coding and combinatorics, block ciphers, side channel attacks as well as mathematical aspects. All the revised papers will be published by Springer as a volume of the Lecture Notes in Computer Science series.

Conference on Implementation and Application of Automata

August 12–15, 2010, Held at the University of Manitoba
Organizer: Michael Domaratzki (University of Manitoba)

This was the 15th year of this conference, with 51 participants including three invited speakers, from sixteen nations representing North America, Europe and Asia. There were 52 submissions, of which 26 were accepted as full papers and 6 as short papers. The 50 % acceptance rate for full papers is lower than in recent editions of the conference, due in part to a slightly higher volume of submissions. Preproceedings were distributed at the conference, and papers will appear in a volume of Springer *Lecture Notes in Computer Science* (LNCS) in early 2011.

The conference consisted of fourteen sessions. Three of the sessions consisted of invited talks. In the first session of the conference, Madhusudan Parthasarathy (University of Illinois Champaign) gave an invited talk *Deciding emptiness of automata with auxiliary storage*, describing a unified approach to deciding the emptiness of automata with auxiliary storage such as pushdown stores or queues.

Karen Rudie (Queen's University) gave Friday's invited talk, *A summary of some discrete-event system control problems*. Rudie described the relationships between automata theory and classical control theory in engineering, highlighting the boundaries between efficiently solvable, intractable and undecidable problems in this area.

Natasha Jonoska (University of South Florida) gave an invited talk on the final day of the conference on *Using automata to describe self-assembled nanostructures*. The talk described an algebraic approach to characterizing the possible nanostructures assembled from a set of molecular pieces.

Cyril Allauzen was presented with the CIAA 2010 Best Paper award for his paper, co-authored with Corinna Cortes and Mehryar Mohri, entitled *Large-Scale Training of SVMs*

with Automata Kernels. The paper describes transducer-based methods for improving the efficiency of training SVMs in machine learning applications.

On Saturday afternoon, conference participants visited the Forks National Historic Site in downtown Winnipeg, followed by dinner at Canwest Park.

CIAA 2010 was organized in conjunction with DCFS 2010 (Saskatoon, Saskatchewan) and DLT 2010 (London, Ontario). Both of these events are in related disciplines, and many participants from overseas were able to attend more than one of the meetings. CIAA will be held in Blois, France in 2011 and Porto, Portugal in 2012.

Fields-MITACS Research Meeting and School on Distributed Computing by Mobile Robots

August 15-18, 2010, Held at Carleton University

Organizers: Nicola Santoro (Carleton), Paola Flocchini (Ottawa), Giuseppe Prencipe (Pisa, Italy), Matthew Kellett (DRDC Ottawa)

Distributed robot computing is the study of computability and complexity in systems where the computational entities themselves are capable of movement within whatever spatial universe they inhabit. The field has applications in areas as diverse as autonomous robots moving in a terrain, software agents moving in a network, autonomous intelligent vehicles, wireless mobile ad hoc networks, and networks of mobile sensors.

The four-day meeting and research school brought together approximately 50 researchers, graduate students, and postdoctoral fellows from throughout North America and Europe and from as far away as Japan. The goal was to bring together theorists and roboticists for an exchange of problems, ideas, techniques, and results in the hope of getting a better picture of the state of the art in the field, to identify outstanding open problems and research directions, and to foster collaborative investigation of selected problems. The graduate students and post-doctoral fellows attended it as a research school.

Each day started with lectures, followed by unscheduled talks, and ending with a discussion session on open problems. Over the course of the meeting the topics went from the purely theoretical to the practical and back again. The first day was dedicated to theoretical models of robot computation with three of the organizers presenting overviews of the existing literature and their own work. Nicola Santoro of Carleton University began with an overview of models for robot computation. Giuseppe Prencipe of the Università di Pisa presented a talk on computation by robots with unlimited visibility, one of the dominant robot models in the theoretical literature. In this model, a robot can see all the other robots in the plane even to the point of seeing through other robots and it can accurately measure the robots' locations. It is even possible for more than one robot to share the same point in space, although there are variations on whether the observing robot is able to see the multiple robots or count how many there are. Paola Flocchini of the University of Ottawa presented a slightly more realistic version of this model, computation by robots with limited visibility. This model is essentially the same as the unlimited visibility model with the exception that the robots can only see out to a

certain distance on the plane. The last talk of the day was given by Shantanu Das of Aix-Marseille University who described an algorithm for the formation of sequences of patterns by oblivious robots.

The second day focused on fault tolerance. Xavier Défago of the Japan Advanced Institute of Science and Technology gave an overview of robot models of fault tolerance, where the faults can be anything from an inaccurate compass to a robot that has malfunctioned or run out of power. Maria Gradinariu Potop-Butucaru of the Université Pierre et Marie Curie looked at gathering and convergence when various faults occurred, Koichi Wada of the Nagoya Institute of Technology looked at gathering when the robots have unreliable compasses, and Taisuke Izumi of the Nagoya Institute of Technology studied gathering when the level of multiplicity is uncertain. The afternoon focused on related problems and computations in non-faulty environments: Jeremie Chalopin of CNRS Marseille described exploration algorithms, and Mark Yamashita of Kyushu University indicated research directions. The open problem session was initiated by Richard Tan of University of Oklahoma who led the discussions and chaired the session.

Contrasted with these theoretical models was the lecture on the third day by Lynne Parker of the University of Tennessee on her work with real-world robots. It became clear from her lecture that even some of the most basic assumptions of the dominant theoretical models diverged from what was possible in reality. Measurement of distance and direction by real-world robots is made highly inaccurate by the noise of the typical sensor, meaning that the impossibility results predicted by the theoretical model were unlikely to occur in real-world setting. Not only are the sensors less accurate, they are also very expensive, meaning that the robots in real-world scenarios presented by Parker were heterogeneous in regard to their abilities as opposed to the homogeneous robots generally used in the theoretical models.

The third day continued with lectures by Evangelos Kranakis, Xu Li, Elio Velasquez, and Gabriel Weiner (Carleton University), on sensor networks where robots place sensors or the sensors themselves can move, and on simulation environments. Finally, Pierluigi Crescenzi of the University of Florence addressed the new research challenges and chaired the open problem session.

The fourth day focused on lectures about robots moving in graphs and other discrete environments as opposed to the continuous environments that had been the focus of the meeting up until that point. This day was a return to the more theoretical aspects of robots: Andrzej Pelc of the Université du Québec en Outaouais, Arnaud Labourel of the Université de Bordeaux, Euripides Marcou of University of Central Greece, Lelia Blin of Université d'Evry, and David Ilcinkas of CNRS Bordeaux, all focused on rendezvous and exploration by oblivious robots. Lali Barriere of the University of Cataluna chaired the open problem and discussion session.

The open problem and discussion sessions generated a lot of discussion and the introduction of a number of interesting new open questions. There was also ample opportunity for discussions and meetings between collaborators on ongoing research.

Fields-MITACS Industrial Problem-Solving Workshop

August 16-20, 2010, Held at the University of Toronto

Organizers: C.S. Bohun (UOIT), H. Huang (York), G. Lewis (UOIT), R. Melnik (Wilfrid Laurier), N. Nigam (SFU), S. Sivaloganathan (Waterloo)

This event is the latest in the widespread effort to strengthen the connection between industry and the academic community. By encouraging academics to focus on problems in industry, they are exposed to interesting and topical problems that are applicable to industry. By industrial problems, we mean those with either a commercial or social benefit, whether it be the optimal design of an electric motor, modelling financial options or classifying mother/child interactions. This activity helps industry by enabling them to pose their problems to teams of individuals with whom their concerns are paramount. In doing so, industry gains access to experienced mathematical modellers and problem-solvers. .

Thus the objective of the FMIPW is to connect industries with faculty, postdocs and graduate students who have expertise in industrial case studies. This interaction is fostered in the specific context of a problem-solving session over 5 days. The case studies considered in the session should of course have a significant mathematical or statistical content. As this effort is ongoing, a repository of reports from study groups is maintained as part of the Mathematics in Industry Information Service found at www.maths-in-industry.org/, where both industrial and academic participants can see what can be achieved in the brief five days devoted to their problem.

This year five problems were presented and participants included roughly 50 academic experts (including mathematicians and statisticians), and experts from industry. On the first day, the industrial sponsors stated their problem. The academic representatives then broke up into teams of 6 to 10 people, and each team chose a leader who was responsible for keeping the team on course. Each team spent the next 3 days working on solutions to the problem, presenting their solutions on the final day of the workshop.

After an early breakfast, Calidus-Fathom Machinery Inc. opened the workshop with a problem of position sensing – it's one of those problems that sits in the back of your head nagging at you year after year. This year Calidus-Fathom emailed our group and after a few visits to the company and follow-up emails, it was decided that the time was ripe for this problem to be seriously considered. The next problem was posed by Mapleridge Capital Corp. It was a problem involving irreversible time series in the financial marketplace – specifically can one determine whether or not the market was behaving in a reversible or an irreversible manner. After thinking about coupling ideas from finance and thermodynamics (not joking here!), the next talk was a fascinating one about Flying Probes and a two dimensional motor by Acculogic Inc. What is sought is an optimal way of reaching a variety of locations – which echoes a bit of the first talk. These flying probes move with such speed and accuracy that must be seen to be believed! The tricky part of this problem is that the researchers are constrained to optimize only certain aspects; as these are improved and brought online, they may delve deeper into the control logic. The number of possible solutions is astronomical, yet after watching the video of the device, it was clear that the way the current paths are chosen could be improved.

It was then time for a coffee break and the opportunity to ask some questions of the first presenters to clarify our thinking. We then filed back into the auditorium for the last two talks. The first problem concerned signals in the brain and was posed by the University of Toronto's Hospital for Sick Children. Specifically, if two signals in the brain are synchronized, how far apart should they be to be considered healthy. This is an interesting problem for which mathematical models are just beginning to be developed. The ramification of clinical data to test the models is a coup for modellers and we are eager to see the progress that is made over the week. Last up is a representative of the Ottawa Hospital Research Institute pointing out the fractal nature of many biological processes. Levels of self-similar patterns occur in both the structure and the timing of biological processes. This is quite a broad topic and watching the presentation I can't help but wonder how it's going to be tackled.

With the end of this last talk we break for lunch and everyone discusses what we have seen and what problem we all might possibly poke our heads into. I could tell from the enthusiasm that this was going to be a successful workshop with a few sleepless nights.

All-in-all this year's workshop was quite a success with some problems being pursued as part of the research program of a few of the academics. Participants from industry are invited to contact me if they have a problem that they'd like to bring to a workshop. There are many such opportunities throughout the year and for a relatively small fee they really can make significant progress on a problem and focus on the questions that are the critical issues for their endeavours. Participants from universities are challenged to see if they can apply their research to real-life problems and to investigate new fields that could benefit from connections only they can make.

14th Conference on Developments of Language Theory

August 17 - 20, 2010, Held at University of Western Ontario

Organizers: Yuan Gao, Hanlin Lu, Cheryl McGrath, Angie Muir, Shinnosuke Seki, Sheng Yu (Chair), (all from UWO)

The DLT conference series, of which this year's was the 14th occurrence and the first time that it was held in Canada, is the most important conference series in language theory. Thirty-two regular papers were presented, in addition to six invited talks given by Dora Giammarresi (Rome), Markus Holzer (Giessen), Oscar Ibarra (Santa Barbara), Lila Kari (London, Ontario), Michel Rigo (Liege), and Grzegorz Rozenber (Leiden). There were also 6 posters on display. The number of participants was 93, from 21 countries.

The talks and posters included advances in classical problems, e.g. the Černý conjecture and language equations, and as well as studies of a number of new models in language theory. Various results on different complexity measures of language objects and results on two-dimensional languages were also presented. Several papers were motivated and inspired by biology or biochemistry.

DLT 2010 was sponsored by the Fields Institute, The University of Western Ontario, European Association for Theoretical Computer Science, and Academia Europaea.

The proceedings of the conference were published as a special issue of Springer Lecture Notes in Computer Science (LNCS 6224).

Workshop on Approximations, Asymptotics and Resource Management for Stochastic Networks

August 18–21, 2010, Held at Carleton University

Organizers: Minyi Huang and Yiqiang Zhao (Carleton)

The Fields-MITACS workshop on approximations, asymptotics and resource management for stochastic networks was held at Carleton University under the joint sponsorship of the Fields Institute and MITACS, the Laboratory for Research in Statistics and Probability and the School of Mathematics and Statistics of Carleton University. The goal of the workshop is to promote research and applications of stochastic networks. This workshop brought together near 50 participants, including researchers, students and post-doctoral students from Canada and elsewhere.

The workshop provided a forum for people from mathematics, engineering, management, and industry to exchange research ideas, and an opportunity for students to learn of recent developments in related areas and to interact with researchers and other students.

It featured two six-hour tutorials, 6 one-hour invited talks, and 4 thirty-minute invited talks. The talks covered a wide range of topics, including queueing networks, subgeometric ergodicity of Markov chains, search algorithms, and Internet congestion control.

The content and technical depth of the two tutorials was carefully designed to benefit both graduate students and researchers. In the first series of tutorials, Michel Mandjes of the University of Amsterdam and CWI, introduced Levy-driven queues, and covered stationary workload, transient behaviour of queues, and asymptotics of workload. The second series of tutorials was delivered by Masakiyo Miyazawa of Tokyo University of Science. He focused on tail probabilities of queues in the quarter plane and combined several tools, including random walks, moment generating functions and complex analysis, to obtain exact tail asymptotics.

The six one-hour invited talks covered a diverse range of topics related to stochastic models. Doug Down of McMaster University used fluid limits to analyze state-dependent response times in shortest remaining time queues. Yuanyuan Liu of Central South University considered subgeometric ergodicity for continuous time Markov chains. Yuliy Baryshnikov of Alcatel-Lucent Bell Labs described search algorithms for a randomly located object and presented the associated chaotic phenomenon. Hui Li of Mount Saint Vincent University presented light-tailed behavior of random walks in the quarter plane. Peter Glynn of Stanford University introduced a martingale approach for explicit computations and asymptotics in finite buffer models. Ravi R. Mazumdar considered bandwidth allocation for internet flow control and analyzed related constrained optimization problems.

Additional research talks were given mainly by graduate students and postdoctoral fellows reporting on their recent research progress.

Workshop on Homotopy Theory and Derived Algebraic Geometry

August 30 – September 3, 2010, Held at the Fields Institute

Organizing Committee: P.G. Goerss (Northwestern University), J.F. Jardine (Western Ontario)

In May 2007, we organized a workshop at the Fields Institute on stacks in geometry and topology. This was the centerpiece of a two-month program in Spring 2007 intended to explore interactions between algebraic geometry, algebraic topology, and homotopy theory. What we did not realize at the time was that this conference and the entire program caught the wave of the emerging field of derived algebraic geometry. In a remarkable series of talks, many by mathematicians with relatively recent PhDs, we saw the implementation and application of derived schemes, derived stacks, higher categories, and the attendant homotopy theory across a broad spectrum of geometric and topological subjects.

This 2010 workshop was intended as a follow-up to the 2007 conference: we envisioned revisiting the field three years later to assess what had happened and to see where we are going. In the end, however, the conference became much more than that, for we found that derived algebraic geometry and the associated homotopy theory has applications across a broad selection of fields, including algebraic topology, algebraic geometry, homotopy theory, category theory, and the more topological side of mathematical physics. This led to an eclectic and wide-ranging series of talks, some from established research mathematicians, but many from some of the emerging stars in the field. It also led to a large, vibrant and young audience: we filled the main lecture hall at the Fields Institute for a week with research mathematicians and graduate students from all over the world.

Ralph Cohen (Stanford) was an early speaker; his talk on string topology aptly captured how physics inspired purely topological questions, and how the topological answers gave insights into the original physics questions. On the same day, Clark Barwick (MIT) explored remarkable recent progress on an old conjecture of Gunnary Carlsson's on the equivariant nature of algebraic K -theory. This was an example of how the new viewpoint could inform progress in established areas. Later in the week, John Francis (Northwestern), in his talk on E_n -geometry, was able to give a conceptual framework for

and a lucid proof of a result that gathered together all sorts of known results which, heretofore, had only had ad hoc computational arguments; what had been oddities before suddenly became a major theorem. Niko Naumann (Regensburg) used his background in number theory and algebraic geometry to give some remarkable calculations for groups related to Hopkins-Miller topological modular forms. And, as a final example of the breadth of the conference, Andre Henriques (Utrecht) gave a talk on the algebraic topology of conformal field theories and related mathematics. In the end we had eighteen

hour lectures, ranging from chromatic stable homotopy theory (Mark Behrens) to motivic homotopy theory (Dan Isaksen), on out to abstract homotopy theory (Giancalo Tabuada), and mathematical physics.

A remarkable feature of this workshop was the relative youth of the participants. A very large proportion of those in attendance were graduate students, postdocs, a researchers within ten years of their Ph.Ds. This same observation applies to the speakers as well and, it should be noted, this was simply the end result of putting together the best speaker list possible.

A successful workshop is possible only with the help of many people and organizations. In this case, Fields Institute and its staff played the primary and essential role. The staffs at Northwestern University and the University of Western Ontario helped as well. Travel for participants was partially supported by the NSF and NSERC.

Big Ideas in Mathematics Education Symposium

October 25, 2010, Held at the Fields Institute

Organizers: Dan Peter, Walter Whiteley (York)

The Fields Institute hosted a discussion on Big Ideas in Mathematics on October 25, 2010. About 70 people participated, including Early Childhood Educators, Kindergarten to Grade 12 (K-12) classroom teachers, school board mathematics coordinators, and University and College faculty in Mathematics and in Mathematics Education. For school board staff, the context for the discussion was planning for future revisions of the Ontario Mathematics Curriculum, pre-Kindergarten to Grade 12, which is expected to be organized around “Big Ideas” (as is currently true of other recent newly adopted curriculums in Ontario). A related issue, for university faculty, is the reworking of the Ontario University programs in the larger terms of University Undergraduate Degree Level Expectations (UUDLES) laid out by the Council of Ontario Universities. Funding for the day came from the Fields Institute and MITACS; organizing was done through the “Three Year Curriculum Project” whose steering committee is drawn from the Ontario Association for Mathematics Education, the Ontario Mathematics Coordinators Association, and the Fields Institute Mathematics Education Forum.

The format of the day was “open space”. Topics for three rounds of small group discussions were suggested and posted by the participants. What emerged were diverse discussions including themes such as mathematical concepts and areas recognizable as big ideas, such as “uncertainty (and chance)” and “transformations and invariance”; mathematical processes as big ideas, including areas such as rich problem solving, reasoning; implementation and pedagogical challenges: the role of representations (technology, manipulatives) and sense-making; and transitions between levels of education.

Marion Small, who has written extensively on Big Ideas, helped frame and reframe our discussions. She gave multiple examples that some authors identified as big ideas in mathematics or mathematics education, showing a diversity of scale, conceptual levels,

and connections. She reminded us that this is a discourse still being developed, open to multiple interpretations. She also noted her own experience in developing these new ideas, starting with grouping specifics across a few grades, and then more recently moving on to larger groupings, running over larger sections of the K-12 curriculum, and now connecting these larger ideas back to pedagogy and curriculum in more specific contexts.

Few conclusions were drawn, aside from the facts that the discussion is in its early stages and therefore incomplete, and that implementation support can be more important than the actual written curriculum itself. In general, the participants expressed the need to build connections among areas (strands), grades, themes and processes. They felt that there was some hope that reworking the mathematics curriculum around big ideas would be a positive step forward for students, classroom teachers, and parents.

*Jacqueline Hill (Durham School Board),
Daniel Peter (York), and Walter Whiteley (York)*

Annual Conference of the Individual Finance and Insurance Decisions Centre

October 28, 2010, Held at the Fields Institute

Organizers: Narat Charupat (McMaster), David Promislow (York), Moshe Milevsky (York)

The theme for this 10th annual conference of IFID was models for lifecycle finance, insurance and economics.

Lifecycle theory studies patterns of consumption, savings and investment at different stages of an individual's life, including both the working and retirement years. This is of interest to various groups. Economists are interested since such patterns affect the accumulation of capital, which can impact many aspects of economic planning. Individuals are interested in conducting their affairs in order to maximize the satisfaction they obtain from consumption over their lifetime.

The main ideas in lifecycle theory were developed by Franco Modigliani in 1954, who investigated mechanisms available to individuals to accumulating capital during their working lifetime and using it for consumption in the retirement phase. In 1985 he was awarded a Nobel prize for his work in this area.

A major extension to the theory was made in 1965 by Menachem Yaari, from the Hebrew University, who incorporated into the model the randomness of the time of death, replacing the deterministic time present in the earlier versions.

We were indeed fortunate to have Yaari as the keynote speaker at the conference. He gave a fascinating account of the ideas and thinking that led to his groundbreaking 1965 paper, a work that inspired much of the subsequent developments in the field.

We were also fortunate to have as a participant in the conference, Scott Richard from the University of Pennsylvania, another notable figure in the early development of lifecycle

theory. In 1975, Professor Richard applied the concept of random lifetimes and the use of life insurance, to generalize a classical 1971 paper of Richard Merton on optimal consumption and portfolio rules for an individual faced with a choice of several financial assets to invest in.

In addition, the conference featured a group of highly distinguished international scholars who have made leading contributions to lifecycle economics. Their presentations involved both theoretical concepts as well as more practical methods for helping individuals make optimal financial decisions.

A major issue that arose from Yaari's paper was the role of life annuities in financial planning. Yaari had showed that under certain assumptions it is highly desirable to purchase life annuities to provide an extra return above a comparable fixed income investment. However, few people actually purchase them, leading to what has been called the "annuity puzzle". The conference featured a few papers discussing the role of annuitization and providing some insights into the difference between the theoretically optimal and the actual levels of annuity purchase.

Other areas of discussion included extended models for incorporating life insurance into lifecycle theory, and some new methods for modelling the randomness of labor income.

In addition to Yaari and Richard, the speakers and discussants at the conference were Larry Kotliko (Boston University), Stan Pliska (University of Illinois), Takao Kobayashi (University of Tokyo), Siu F. Leung (Hong Kong University of Science and Technology), James Feigenbaum (Utah State University), Sherman Hanna, (Ohio State University), Tom Salisbury, (York University), Huaxiong Huang (York University), Tom Davidoff (University of British Columbia), Jim Davies (University of Western Ontario), and Svetlana Paschenko (University of Virginia), the winner of the second annual Ph.D. student competition.

Workshop on Technology Integration in Teaching Undergraduate Mathematics Students

October 29, 2010, Held at the Fields Institute

Organizers: Chantal Buteau (Brock), Daniel Jarvis (Nipissing), Zsolt Lavicza (Cambridge)

Can teaching and learning in undergraduate mathematics be improved by technology use?

On October 29, 2010, mathematics education researchers Chantal Buteau (Brock), Daniel Jarvis (Nipissing) and Zsolt Lavicza (Cambridge) hosted a one-day event at the Fields Institute, entitled *Workshop on Technology Integration in Teaching Undergraduate Mathematics Students*. This was the second of two such workshops, the first having been hosted in French at the Centre de recherches mathématiques (CRM) in Montréal on October 1, 2010. These workshops, with programs comprised of a keynote presentation, a research report, and three discussion sessions, were mainly aimed at mathematicians

working in departments of mathematics, including graduate students who teach undergraduate courses.

Discussions were stimulated during both workshops on when, where, and how technology should be implemented in mathematics classrooms. According to a recent national online survey regarding the use of Computer Algebra Systems (CAS) by Canadian mathematicians in post-secondary mathematics instruction, 69 percent of the survey respondents indicated that they use CAS in their teaching. This finding was highlighted by Buteau and Jarvis in their research presentation.

The survey was completed in 2009 as an extension of Lavicza's doctoral study, in which he surveyed over 4500 mathematicians from Hungary, the United Kingdom, and the United States. In his work, Lavicza debunked myths such as the notion that few professors use CAS technology in their teaching, or that only younger professors adopt technology for instruction. He also demonstrated, using Structural Equation Modeling, that the strongest predictor for the use of CAS in one's teaching was the use of CAS in one's research.

In his keynote presentation entitled, *Postsecondary Mathematics Education and Technology: Some Personal Views from a Mathematician's Perspective*, former Secretary General of the International Commission on Mathematical Instruction Bernard Hodgson (Laval) began an insightful presentation by stressing the importance of mathematicians' contributions to mathematics education, highlighting five historical examples of worldwide renowned mathematicians who have made significant contributions to mathematics education: Henri Poincaré, George Pólya, Felix Klein, Hans Freudenthal, and Hyman Bass. He further referenced examples of collective involvement, such as the Education webpage on the CMS website, the education columns in CMS Notes and AMS Notices, and, at the international level, the strong existing links between ICMI and its mother organization, the International Mathematical Union (IMU). Some departments of mathematics have incorporated core courses dealing with programming and/or CAS use into their undergraduate mathematics programs. Why would such a course be needed and with what particular aims? How do these mathematics departments maintain the level of technology skills and enthusiasm among students following such a core course? Should the content be aimed at learning CAS/software, or new mathematics, or both?

These questions were at the heart of the first discussion session, hosted by Laurent Delisle (Montréal), E.J. Janse van Rensburg (York), and Yvan Saint-Aubin (Montréal), and entitled: *Integrating an additional Junior course in programming and/or CAS use: Issues and impact on curriculum*. Through their brief presentation of two courses developed and delivered at the Université de Montréal and at York University, the presenters discussed and stressed the different aims of the courses and the issues stemming from their experiences teaching the courses. In the first of these courses, no new mathematics was introduced, the content emphasizing the ties between mathematics and the structure of CAS software from basic tools to list manipulation. The second course, offered in the second year, was based on open-ended investigations and the

submission of written reports.

Many Ontario mathematics departments have begun the academic review process in light of the province's University Undergraduate Degree Level Expectations (UUDLEs). In this context, it becomes natural for departments to address the question of digital technology's role in their undergraduate programs, how it is (or should be) integrated into their courses, and how it evolves throughout the program.

This served as the basis for the second discussion session, hosted by Jane Heffernan (York) and Walter Whiteley (York) with Franco Saliola (UQAM), entitled: Rethinking the undergraduate mathematics curriculum: What role does technology play? In this session, presenters discussed some of these issues through a presentation of UUDLEs, specific to digital technology, on curricular mapping as experienced at York University. There was a lengthy discussion on the continuum from Statistics (which has a heavy penetration of technology), through Applied (with "capstone course"), Math for Commerce (Minitab, Excel, "R" statistics), Math for Education (dynamic geometry, Maple, Google SketchUp, Spherical Easel, Interactive Whiteboards), to Pure Math (little technology apart from Maple in one course). Presenters felt that a "coming shift" was imminent, noting that technology is ubiquitous, and also quoting Zalman Usiskin (Chicago) that perhaps "use technology when appropriate" may soon be replaced with "use pencil/paper when appropriate" in mathematics curricula.

In the assessment of students' knowledge, particularly in final exams, the use of pencil/paper, and possibly of a "standard calculator," seems to be the predominant approach. Indeed, in the Canadian survey mentioned above, only 22.3 percent of all CAS user respondents integrate CAS, at least occasionally, in final exams, and 26.3 percent in classroom tests. But what then is the implicit statement being conveyed to our students when we explicitly exclude technology use in our final examinations? Are we saying that the development of a mathematical practice that makes pertinent use of technology is not a learning goal recognized by the institution?

Hichem Ben-El-Mechaiekh (Brock) and France Caron (Montréal) addressed the topic of assessment in the third and final discussion session entitled Assessment in mathematics courses integrating technology: Technical/ pedagogical challenges and curricular considerations. Diagnostic, formative (ongoing) and summative (unit- or course-end) forms of assessment involving technology were discussed. Session hosts asked workshop participants to reflect on practice and volunteer information regarding types of assessment.

Approximately 45 individuals attended both the CRM and Fields workshops in total, and good discussions were enjoyed in the various sessions and during informal gatherings.

Chantal Buteau (Brock), Daniel Jarvis (Nipissing) and Zsolt Lavicza (Cambridge)

Weekend Workshops on Algebraic Varieties with Special Emphasis on Calabi-Yau Varieties and Mirror Symmetry

March 6-7, 2010, Held at the Fields Institute

Organizers: Noriko Yui (Queen's) and James D. Lewis (Alberta)

This series of workshops, inaugurated in 2003 by James D. Lewis (Alberta), Stefan Müller-Stach (McMaster, now at Johannes Gutenberg University Mainz) and Noriko Yui (Queen's), has entered its eighth year. It is now a biannual event at Fields with a meeting in the Fall, and another in the Spring.

The subjects covered in the workshops ranges widely from arithmetic/algebraic geometry, Galois representations and complex geometry, to mathematical aspects of string theory. These workshops are well attended with about 25 to 30 participants from Canada and abroad, consisting of well established leaders working on the leading edge of the subject, a very promising next generation of younger researchers (including graduate students and postdoctoral fellows), and leading experts in closely related areas where fruitful interactions are deemed likely. Indeed, these workshops have now established their prominence in the community and attract speakers and participants from all corners of the world – e.g. from the United States, Europe, Japan and China. In the near future, we are hoping to have speakers and participants from Mexico and Latin America as well.

The workshops are generally self-supporting, supplemented by a grant of \$2,000 from the Fields Institute. As a general rule, postdoctoral fellows and graduate students are supported by their supervisors and by the Fields Institute grant to cover expenses. The organizers solicit speakers in advance, and postdoctoral fellows, graduate students are especially encouraged to give talks.

The pedagogical aspects of the workshops are emphasized in the choice of topics so that every participant can benefit from the talks and through informal discussions.

In this case, there was a little bit more emphasis on the Hodge theory aspects of the subject, as evident by the talks given by Gregory Pearlstein (Michigan State), Patrick Brosnan (UBC), James D. Lewis (Alberta) and Su-Jeong Kang (Providence College). These workshops also provide a forum for young participants to get first hand opportunities to discuss their problems and results with mid-career and senior researchers. They also serve as a useful forum for researchers to present new ideas that often lead to future collaborations and publications. This formula has worked very well in the past, and did so again this time.

Workshop on Discrete and Computational Geometry

First Joint North American Meeting on Industrial and Applied Mathematics (SMM-SIAM-CAIMS)

December 7-10, 2010, Held at the Universidad del Mar, Huatulco, Mexico

Canadian Organizers: Uri Ascher (UBC), Barbara Keyfitz (former Director of the Fields Institute), Mike Mackey (McGill), Bob Russell (SFU)

In August, 2008, officials from the Mexican Mathematical Society (or SMM -- Sociedad Matematica Mexicana) expressed interest in organizing a joint SMM/CAIMS/SIAM meeting in Mexico in 2010. As a result, I was approached by Alejandro Adem and in turn by the CAIMS Board in early Fall, about the proposed meeting. The CAIMS subsequently gave unanimous approval to proceed with plans for the meeting. A Steering Committee was struck, with equal representation from each of the three participating countries.

The primary intention of the meeting was to bring together applied computational scientists, mathematicians, researchers and students with interdisciplinary interests, from Canada, the U.S., and Mexico. Among the purposes was the enhancement and strengthening of academic relations between the three countries with respect to applied and industrial mathematics. The meeting was organized around eight workshops on research topics in applied mathematical fields (chosen by the local organizers, largely to highlight research strengths in Mexico). Additional topics were discussed in a general workshop and in the poster sessions. For all minisymposiums except the latter, the talks were by invitation. Details about the meeting are available at the meeting website www.smm.org.mx/namiam10/.

It was regrettable that several intended participants from Canada were unable to attend due to inability to obtain suitable airline flights or because of last minute commitments at home. For those who did attend, the meeting was a great success by almost any measure. Several colleagues mentioned how stimulating it was to find out what our U.S. and Mexican colleagues are working on in the environment of Huatulco, a beautiful town situated on the Pacific Ocean. As one person put it, the conversations over a plate of Oaxacan mole or a glass of Mexican beer were just as rewarding as the good mix of very high quality presentations and lively discussions at the meeting itself (held on the local campus of Universidad del Mar). All of the Canadian participants with whom I spoke expressed particular gratitude to the CRM, Fields, MITACS, and PIMS for supporting this important international gathering.

The meeting began with welcoming remarks from representatives of the three participating countries (in our case, Mike Mackey), after which people were feted at an outdoor reception by our hosts on the beautiful university campus – Mike noted that it was the first time in his life that he had attended a meeting on a university campus that was literally a botanical garden, and a most lovely one at that. The opening talk on

Separable Least Squares was given by Victor Pereyra (USA). The other scheduled invited talks were from Canadians Mary Pugh (Fluids) and Eldad Haber (Inverse Problems), Mexicans Onesimo Hernandez (Applied Probability) and Gilberto Calvillo (Financial Math), and Roland Glowinske (PDEs) and Gunther Uhlmann (Inverse Problems) from the USA. Mary Pugh was at the last minute unable to attend, and Barbara Keyfitz kindly filled in and spoke about some of her own work in PDEs. These invited lectures were well attended and of very high standard.

There were two special sessions, one in which John Stockie (SFU) gave an animated presentation on industrial mathematics and the Canadian experience through MITACS. It met with great interest from the participants, particularly the Mexicans. The other

session brought together a panel of individuals from each of the three countries who discussed opportunities in applied mathematics from a general perspective. As one colleague pointed out, it was intriguing to note that Mexican applied mathematicians and statisticians suffer from the same constraints as those in Canada – that being somewhat of a branch plant economy, our local industry tends to look to the US for research and development, and that in spite of the favourable treatment of mathematicians and statisticians under the free trade agreement, it is still hard to overcome this prejudice.

There was clear consensus that the minisymposiums were of very high quality. They were organized in parallel streams which often made it difficult for the participants to have much time for discussions; nevertheless, it was possible to attend several minisymposiums. One colleague who had attended the sessions in CFD, Numerical Analysis, and Math Biology commented that while covering a pretty broad range of topics, the minisymposiums still focussed on a couple of specific areas, which kept them interesting. Canadian organizers of these minisymposiums provided the following enlightening comments about their own sessions and about the meeting as a whole:

Optimization and Operations Research (Patrice Marcotte (U of Montreal)): It was unfortunate that, due to the main Mexican airline Mexicana having gone bankrupt, several of the Canadian lecturers had to cancel. Fortunately, the talks that were given were of very high quality, and those in attendance commented that the minisymposium was a thoroughly enjoyable one. A list of participants of this and the other minisymposiums, as well as the titles of their talks, are available on the meeting website.

Inverse Problems and Control (Uri Ascher): Some excellent talks were given, including those by van den Doel (Canada) and Ghatas and Heinkenschloss (USA) (and, I am sure, by Uri himself). He commented especially on the very fruitful discussions he had had with the above people as well as Kevlahan (McMaster), Gomez (Mexico), and Nocedal, and Pereyra (US).

Oil, Weather and Geosciences Modelling (Nicholas Kevlahan): Although there were originally four Canadians scheduled to give talks on the full range of symposium topics, two unfortunately had to cancel at the last moment. Nicholas spoke about a new dynamically adaptive wavelet method being developing for the dynamical core of the next generation of climate models, and Francis Poulin gave a talk on the three-dimensionalization of a barotropic instability in ocean flows. The Mexican participants concentrated on the geosciences part of the symposium, and it was interesting to see the strengths of Mexican applied mathematics in modelling earthquakes and oil reservoirs. Moreles presented a problem related to porous medium diffusion in oil well reservoirs, Chavez showed impressive supercomputer 3-D simulations of earthquakes, and Gomez showed how optimization techniques can be used to characterize the structure of fractured oil reserves. The two U.S. participants were Castillo, who described a new general curvilinear coastal ocean model, and Drummond, who presented new software tools for geophysical applications.

Biomathematics (Mike Mackey): The Canadian contingent provided three extremely interesting lectures about quite diverse areas. These were given by Dan Coombs (UBC), Gerda de Vries (Alberta), and Olivier Barriere (U of Montreal). The workshop was of

particular value since it offered a chance to both learn about work of previously unfamiliar Mexican colleagues and to be updated on what U.S. colleagues were working on. However, as with all meetings, the most important aspect was the informal conversation at breaks and between lectures as it allowed one to more fully appreciate the richness of the diversity in biomathematical research as well as to cement one's belief that there is a rich area for further collaborative efforts between researchers in our three North American countries.

Applied Probability and Statistics (David McDonald (U of Ottawa)): The Mexican presentations were of a high level (and were given in English). They included the one by Chavez on the construction of a continuous parameter sequence of random probability measures and its application in continuous-time nonparametric modeling, by Rodrigues concerned with the goal of reducing the number of pollution alerts in the whole of Mexico City when the excess levels were concentrated in specific problem areas, and by Diaz on a spatio-temporal model for lightning-caused forest fire ignitions. The talk by Mogens Bladt on classical phase-time distributions and the extension to heavy tailed distributions was particularly clear and interesting. (David's own talk was on performance of WiFi protocols).

Financial Mathematics and Economy (Tom Salisbury (York)): The other organizers were Kay Giesecke (Stanford) and Beatriz Rumbos (ITAM). There were 12 talks, and a lively audience, which engaged the speakers in discussion. Despite some cancellations, four speakers from Canada delivered lectures – two faculty (Tom Hurd from McMaster and Salisbury), and two students (Meng Han from Toronto, and Oumar Mbodji from McMaster).

Computational Fluid Dynamics (John Stockie): The speakers from Canada were Francis Poulin (Waterloo) and Stockie. Poulin's presentation described an application of spectral methods in the simulation of shear flows in the atmosphere, applied to studying the nonlinear stability of vertical structures. Stockie presented a porous medium model for sap flow in trees, along with numerical simulations being used to assist the Canadian maple syrup industry in developing optimal harvesting methods. Other talks in the CFD minisymposium focused on immersed boundary simulations for fluid structure interaction, algorithms for interfacial flows, flow in porous media, and parallel algorithms.

Numerical Analysis and Linear Algebra (Chen Greif (UBC) and Russell): The other organizers of the sessions were Humberto Madrid (Mexico) and Daniel Szyld (USA). The minisymposium themes were centred around recent developments in numerical analysis, scientific computing, and numerical linear algebra. There were 14 talks, presented in 5 sessions spanning the course of two days. The sessions were very well attended. The talks featured a remarkably diverse range of topics, from numerical linear algebra, to various flavors of the numerical solution of differential equations, to challenging applications. Each session featured speakers from each of the three participating countries and were scheduled to ensure that there was a high level of diversity in each of the individual session, which contributed to the good level of attendance. Canadian speakers were Xiao-Wen Chang (McGill), Eusebius Doedel (Concordia), Steven Ruuth (SFU), Chun-Hua Guo (U of Regina) and Greif. The high

level of research conducted in Mexico and the US in this area was exemplified by the quality of talks given by speakers from these countries as well.

In conclusion, I reiterate the comments of my colleagues who expressed a high degree of enthusiasm over this joint meeting. There was a consensus by all that the meeting had been a great success and that it is worthwhile to have follow-up meetings in the future. This possibility is currently being investigated. The generous financial support provided by the CRM, Fields, MITACS and PIMS was critical for the success of the meeting. On behalf of CAIMS, the meeting participants, and myself, I would like to express our deep appreciation for this support.

Bob Russell (SFU), CAIMS Past-President

Workshop on Combinatorial Algebra Meets Algebraic Combinatorics

January 21 – January 23, 2011, Held in Thunder Bay

Organizers: Sara Faridi (Dalhousie), Anthony Geramita (Queen's University and University of Genoa), Adam Van Tuyl (Lakehead), Adam Van Tuyl (local host, Lakehead).

One of main goals of the workshop is to establish and develop an on-going dialogue between two distinct research groups which have been using different techniques to study similar mathematical problems – algebraic combinatorialists working on the representation theory of symmetric groups, and commutative algebraists studying minimal free resolutions and inverse systems. Since the first meeting in January

2004, these two groups have met on a yearly basis to discuss and share new ideas.

The conference opened on the Friday afternoon with a colloquium talk by Anthony Geramita. He began with an historical overview of Waring's Problem: given a positive integer k , is it possible to write any positive integer as the sum of at most s k -th powers of positive integers? For example, every positive integer is the sum of at most four squares. Using this classical problem as a backdrop, Geramita then described the analog of Waring's Problem for homogeneous polynomials, giving an overview of recent progress on the problem. As he noted, Inverse Systems were used to translate the problem into one, which was amenable to an attack using the methods of modern algebraic geometry. The problem was completely solved by Alexander and Hirschowitz a decade ago and represented a major advance by solving a problem, which had been around for over a hundred years. Geramita also explained several other manifestations of Waring's Problem concerning higher secant varieties for classical algebraic varieties.

The remainder of the conference was held on the last two days, consisting of five invited talks, given by Nantel Bergeron (York), Francois Bergeron (UQAM), Jessica Sidman (Mount Holyoke), Victor Reiner (Minnesota), and Jerzy Weyman (Northeastern), and nine contributed talks. The topics were a mixture of algebra and combinatorics. In fitting with the theme of the workshop, the algebra talks described how a particular area of combinatorics was needed to derive an algebraic result, and vice versa for the

combinatorics talks. The question period was lively with both research groups providing numerous ideas and suggestions.

Graduate students and post-doctoral fellows were, as usual, an important target audience in the mind of the organizers. We were particularly successful in achieving our goals in this area this year since graduate students and post-doctoral fellows accounted for half of the participants and were involved in a significant way in the program and were able to expose their work to an audience consisting of many experts – of the nine contributed talks, seven were given by graduate students and post-doctoral fellows. Topics ranged from the very new area of Boij-Soderberg Theory to more classical subjects such as the study of monomial ideals, simplicial complexes and cluster algebras.

Representation Theory and Quantization Workshop

February 25-27, 2011, Held at the Fields Institute

Organizers: Ivan Dimitrov, Hadi Salmasian

From its inception, Lie theory, and in particular representation theory of Lie groups and Lie algebras, has derived inspiration from physics, number theory, analysis, and geometry. In turn, it has continuously supplied applications to all of these fields.

Canada has a well-established tradition of strong research in Lie theory. In the past several years a number of excellent young mathematicians joined the existing representation theory groups at various Ontario universities creating a critical mass for intense collaboration.

About two years ago, a group of researchers formed the Network of Ontario Lie Theorists (NOLT). The main purpose of this network is to foster collaboration among mathematicians working in areas connected to Lie theory. The means for achieving these goals include short visits for seminar talks, especially by postdoctoral fellows, as well as an annual workshop held in different cities in Ontario. The inaugural workshop was held in February 2010 at Carleton University. Information about past and forthcoming activities of the Network is available at:
mysite.science.uottawa.ca/asavag2/nolt

The focus of the second workshop, held at the Fields Institute from February 25-27, was on the interplay between representation theory and quantization. The workshop attracted more than 50 participants at various stages of their careers, including several postdocs and graduate students. Three excellent young researchers (two graduate students and one postdoc) were also offered the chance to present their work.

The idea of quantization originated in physics in connection with the uncertainty principle and quantum field theory. The works of Duflo, Gelfand, Kirillov, Kostant, and Segal, among many others, established a mathematical framework for geometric quantization with far-reaching applications. Another link between representation theory and quantization is the concept of quantum groups. Quantum groups first appeared in the physics literature as a tool for studying integrable systems. In the mid 1980's Drinfeld and

Jimbo independently noticed that deformations of certain associative algebras (called universal enveloping algebras) provide a natural algebraic context in which quantum groups can be studied. The theory of quantum groups has since developed rapidly and provided solutions to longstanding open problems in representation theory.

The workshop gathered researchers with diverse points of view towards representation theory and quantization, and showcased connections between these topics in a broad context. There were three main themes throughout the workshop: interplay between representation theory and category theory, geometric methods in representation theory, and quantization. Several talks were related to more than one of these topics thus exemplifying the relationships among them.

The interplay between representation theory and category theory was the subject of the talks by Ivan Penkov (Jacobs University, Bremen) who introduced interesting new categories of modules over infinite dimensional matrix algebras, and Vera Serganova (Berkeley), who spoke about a generalization of the Bernstein-Gelfand-Gelfand reciprocity in the context of supergroups. Oded Yacobi (Toronto) described a categorification of the Fock representation and Bogdan Ion (Pittsburgh) presented a general Poincaré-Birkhoff-Witt Theorem for Hopf algebras in arbitrary tensor categories, a result which unifies many of the classical variants of this theorem.

Geometric methods appeared in the lectures of several speakers, including those by Leticia Barchini and Roger Zierau (Oklahoma State), who used ideas such as associated cycles and non-Riemannian symmetric spaces to construct and classify Harish-Chandra modules and unitary representations. Peter Trapa (Utah) used a recent generalization of the Springer correspondence by Dan Ciubotaru to study unitary modules of the affine graded Hecke algebra. Vera Serganova's extension of BGG reciprocity was based on geometric realization of representations. Arturo Pianzola (Alberta) explained some applications of Galois cohomology in the structure theory of infinite dimensional Lie algebras. Allen Knutson (Cornell) spoke about a new approach for obtaining positive branching formulas – a classical open problem in invariant theory – with connections to the Duistermaat-Heckman measure. The talk by Raul Gomez (UCSD) summarized the results of his Ph.D. thesis about explicit realization of Whittaker vectors of generalized principal series. Prakash Belkale (UNC) spoke about a concrete description of unitary metrics on vector bundles of conformal blocks on suitable moduli spaces of genus zero curves.

As for quantization, several speakers mentioned its direct and indirect connections to their works. Bogdan Ion's results are applicable to quantum groups. Milen Yakimov (Louisiana State) explained his proof of a conjecture by Goodearl and Lenagan about certain quantum deformations of coordinate rings of Schubert cells. Alexei Petukhov (Jacobs University Bremen) spoke about quantization of small nilpotent orbits in the context of generalized Harish-Chandra modules. A key ingredient in Peter Trapa's results on representations of affine Hecke algebras was played by a p -adic analogue of the Dirac operator. The latter idea, i.e., using the spectrum of the Dirac operator, was also used by Roger Zierau, but this time over real numbers. The atmosphere of the workshop was

highly vibrant, with numerous informal discussions taking place after the talks. The excellent conditions provided by the Fields Institute and its helpful staff created an environment for fostering discussions between the participants. The young mathematicians, postdocs and graduate students were the greatest beneficiaries of this workshop because they were able to discuss questions arising in their own research with world leaders in the field.

The wide range of subjects of the presentations definitely served well in broadening the younger participants' scope while it did not seem to affect the audience's interest and enthusiasm in asking questions during and after the talks. At the end of each day, some graduate students engaged in math conversations with the speakers, while a few others took time off to practice Allen Knutson's juggling patterns.

Workshop on Semiotics, Cognitive Science, and Mathematics

March 14-18, 2011, Held at the Fields Institute

A weeklong workshop on semiotics, cognitive science and mathematics took place at the Fields Institute during March 14-18, 2011. This collaborative project involved the Fields Institute, the Department of Anthropology of the University of Toronto, and the *Istituto Italiano di Cultura* of Toronto. The organizing committee consisted of Chair Marcel Danesi (University of Toronto) and Co-Chair Mariana Bockarova (Harvard University).

Semiotics is the science that studies signs and their uses in representation. A sign is something that stands for something or someone in some capacity. In this sense, mathematics has a wide array of signs (digits, numbers, integers) and various operations and functions that specify how mathematical symbols should be utilized in mathematics. The three domains of semiotics are: (1) Semantics, the relationship between the signs and the things to which they refer; (2) syntactics, the relationship between signs and formal structures; and (3) pragmatics, the relationship between signs and the effects on those who use them.

Cognitive science is the interdisciplinary study of language, logic, perception, and its manifestations in humans, other life forms, and machines. It draws upon the fields of anthropology, artificial intelligence, biology, computer science, education, linguistics, neuroscience, philosophy, psychology, and sociology. Several of the workshop presentations during the weeklong workshop encompassed these domains

The workshop explored the following five overarching themes through lectures, discussions, and group activities:

1. The sign-based foundations of mathematical representation
2. Modeling the structure of problems in mathematics through computer algorithms and various programming strategies based on semiotic theory
3. The relation between language and mathematics
4. The relation between mathematical representations and discovery of further

- mathematical knowledge
5. The sign based nature of mathematical learning, and especially the role of metaphor and figurative cognition generally in the acquisition of mathematical notions (based on the work of George Lakoff and Rafael Núñez, *Where Mathematics Comes From: How the Embodied Mind Brings Mathematics into Being*)

On the first evening of the workshop, George Lakoff (University of California, Berkeley, Department of Linguistics) delivered the Nathan and Beatrice Keyfitz Lecture in Mathematics and Social Sciences entitled “The Cognitive and Neural Basis of Mathematics”.

After each presentation, there was a limited time for questions, comments and discussion. At the end of each day’s lectures, however, in the workshop portion of the meeting, ample opportunity for in-depth dialogue was possible. The occasionally lively discussion in these afternoon workshops dealt with various aspects of semiotics, cognitive science and mathematics. Several of the afternoon sessions addressed the basic issues that surfaced in these noteworthy exchanges of ideas. Questions of terminology, *a priori* and *a posteriori* knowledge, the integration and blending of knowledge to achieve creativity, the modeling of mathematics through semiotic structures, and the appropriate way to incorporate mathematics into computer games were among the topics discussed.

As a point of departure, James C. Alexander (Case Western Reserve University, Mathematics; National Science Foundation) pointed out that in an interdisciplinary workshop, it would be useful to have a common terminological ground to facilitate shared points of reference for an informed and meaningful discussion. In this regard, the term metaphor, which has both a traditional literary meaning and a conceptual, cognitive scientific usage, prompted commentary from the audience.

Rafael Núñez (University of California, San Diego, Cognitive Science, co-author with George Lakoff of the influential *Where Mathematics Comes From: How the Embodied Mind Brings Mathematics into Being*) discussed the notion of the “number line”, i.e., a straight horizontal line with numbers, which represents real numbers and each real number corresponds to a point in that line. It is divided into two sections (positive to the right, and negative to the left) with a starting point at “0”. The numbers may continue infinitely. An ongoing issue is whether or not these putative spatial mappings are innate or acquired. Based on field research in Papua, New Guinea, Núñez argued that is not biologically endowed, but rather culturally acquired. Discussion centered on the long-established rationalist versus empiricist philosophical approaches to epistemology.

Mark Turner (Case Western Reserve University, Cognitive Science) addressed the notions of “packing” and “unpacking” in mathematics, which takes into account how humans utilize working memory to achieve creativity through the basic operation of conceptual integration, or blending as developed in his book (with co-author Gilles Fauconnier) *The Way We Think: Conceptual Blending and the Mind’s Hidden Complexities*. In this sense, mathematics relies on the processes of packing and

unpacking to achieve maximum application of previously acquired concepts in novel ways. Discussion centered on the ways in which such blending takes place.

Keith Devlin (Stanford University, Mathematics, author of *Mathematics Education in a New Era: Video Games as a Medium for Learning*) discussed the use of video games as a medium for teaching basic mathematics to children. Because children now use video games quite frequently, the meaningful incorporation of mathematical concepts into such games is a way of reaching this age group. Discussion focused on how to integrate mathematical concepts into these games. Should they be a part of the story line or set asides in which students must solve a problem in order to proceed further?

Several papers addressed directly the relationship between semiotics and mathematics. These include the classic question of dyadic versus triadic representation of the sign (Kumiko Tanaka-Ishii, University of Tokyo, Japan, Computer Science), the use of modeling, or the ability to produce forms that stand for ideas that have a meaning, purpose, or useful function in mathematics (Kalevi Kull, University of Tartu, Estonia), a discussion of the semiosis (the production and comprehension of signs) of mathematical thought (John Deely, University of St. Thomas, Houston), and the basic areas of harmony and disharmony between semiotics and mathematics (Solomon Marcus, Mathematical Section of the Romanian Academy). In this sense, all of the papers that addressed semiotics centrally were about the issues raised by the cognitive scientists in the workshop.

Southern Ontario Groups and Geometry Meeting

April 1-2, 2011, Held at the Fields Institute

Organizers: Megumi Harada (McMaster University), Joel Kamnitzer (University of Toronto), Kevin Purbhoo (University of Waterloo)

Broadly, the subject of this workshop was “groups and geometry”. This was the second workshop on this topic held at the Fields Institute – the first was held in October 2009 – in what we expect to be a regular series. A number of rich branches of mathematics lie at the intersection of these two large areas. More specifically, the main themes of interest were geometric representation theory, group actions on manifolds and varieties, and combinatorial aspects of geometry and representation theory.

The day-and-a-half meeting brought together approximately 50 researchers, graduate students, and postdoctoral fellows from mainly the Southern Ontario area, although we had a significant number of visitors from the U.S. (the University of Michigan and Cornell University). Through the financial support of the Fields Institute we were able to support roughly 20 graduate students and recent Ph.D.s to attend the workshop.

The goal was to bring together the local community of mathematicians whose work is broadly connected to the topic of groups and geometry, to share new results and new

ideas, and facilitate research interaction among faculty and students. The lively discussions both during and in between talks indicates that we succeeded in this aim.

The first day of the workshop was a half-day session, consisting of 3 talks on Friday afternoon. We began with a talk by Mike Zabrocki (York University) on k -Schur functions, in which he explained the connection between Littlewood-Richardson rules and explicit formulas for k -Schur functions within the affine nil-Coxeter algebra of type A . The next talk was given by Bruce Fontaine (University of Toronto) on the geometric Satake correspondence, webs, and the affine Grassmannian. The last talk of the afternoon was given by David Speyer (University of Michigan) on projected Richardson varieties, and the stratification of G/P obtained from them.

The second day began with a talk by Jenna Rachjgot (Cornell University) on finding all compatibly split subvarieties of the Hilbert scheme of points in the plane. Next, Greg Smith (Queen's University) spoke on vanishing of higher cohomology in algebraic geometry and studying the complexity of equations for subvarieties. After a lunch break, Ilya Shapiro (University of Windsor) told us about characteristic classes arising from Lie algebra cohomology and formal geometry. The final talk of the conference was given by Jonah Blasiak (University of Michigan), who described an algebraic method to compute 2-row Kronecker coefficients (tensor product multiplicities for symmetric groups) using crystal bases.

It was great to see such a high level of graduate student participation. Two of the speakers, Jenna Rachjgot and Bruce Fontaine, were graduate students; they both gave very interesting talks about their current work. Overall the workshop was intended to be accessible and relevant to students with compatible interests; the speakers did an excellent job of making this the case. One student remarked that she particularly enjoyed the workshop because all the talks seemed to be geared towards her.

Outside of the lectures, there was also ample opportunity for informal discussions and meetings between collaborators on ongoing research. The main foyer of the Institute was lively during the coffee breaks. In addition, we held a banquet, the main organized social event of the meeting, at the Sky Dragon restaurant in nearby Chinatown. Graduate students and postdocs were subsidized for the event and many of them attended the banquet, thus providing them with an opportunity to meet new colleagues and to network both among themselves and with senior visiting faculty.

Ninth Annual Graduate Student Topology and Geometry Conference

April 2-3, 2011, Held at Michigan State University

Organizers: Cheryl Balm (Michigan State), Christopher Cornwell (Michigan State), Zsuzsanna Dancso (Toronto), Thomas Jaeger (Michigan State), Yael Karshon (Toronto), Benjamin Schmidt (Michigan State), Daniel Smith (Michigan State)

This year, the "GSTGC" brought together 180 participants in the fields of topology and geometry for a weekend of talks by students, and by both young and senior faculty.

Starting from a small gathering of topology graduate students from midwestern universities in 2003, the conference has expanded to include students from 61 institutions all over the US and Canada, and as far away as the UK and Korea. “The conference was a huge success,” said Cheryl Balm, conference organizer and fourth year graduate student at Michigan State, “I can’t wait to see how it continues to grow.”

The primary goal of the GSTGC is to give students a chance to present their work to their peers. “I think the whole conference was a great opportunity for all those involved,” said Andrew Misseldine, a graduate student at Brigham Young. In addition to the 32 student expository and original talks on topics ranging from knot theory to hyperbolic geometry to geometric analysis, four young faculty speakers – David Futer (Temple), Teena Gerhardt (Michigan State), Matt Hedden (Michigan State), and Jean-Francois LaFont (Ohio State) – spoke on topics in their fields of expertise, with an emphasis on tractable open problems. Distinguished speakers Ralph Cohen (Stanford), John Etnyre (Georgia Tech), and Karsten Grove (Notre Dame), spoke about fundamental problems that motivate their studies (string topology, contact geometry, and positive curvature, respectively).

As well as allowing students to gain experience presenting their research, the GSTGC aims to connect students and faculty, and encourage relationships that will last throughout their research careers. During lunch breaks and teas, students and faculty could be found using the common areas to discuss problems new and old. “One discussion [I had with a student] seems likely to have a significant impact on the student's thesis, as I helped him with a key argument,” said Hedden. The learning was not unidirectional, however: “While the conference was intended for the students' benefit, I found that I learned a great deal myself. The student talks were excellent.” “[It was] a fantastic conference,” said Futer, “I had a great time, and so did the Temple students.”

Next year's GSTGC will be held at Indiana University in Bloomington, Indiana. For abstracts of the talks from the Ninth Annual GSTGC and photos from the conference, see www.math.msu.edu/related/gstgc/

2nd Montreal-Toronto Workshop in Number Theory

April 9-10, 2011, Held at the Fields Institute

Organizers: Eyal Z. Goren (McGill), Stephen Kudla (Toronto)

The Montreal-Toronto Workshop in Number Theory is a joint initiative, conceived by us as a way to foster stronger relations between the strong groups in number theory and arithmetic geometry in the two cities. The workshop enjoys financial support from both the CRM at Montreal and the Fields Institute at Toronto.

The second workshop took place at the Fields Institute in Toronto on April 9-10, 2011. The program was devoted to the arithmetic of Hilbert modular varieties.

There were 19 participants from Montreal and about a dozen from Toronto, including graduate students, postdoctoral fellows, faculty and visiting faculty.

The program started Saturday morning at 9:00 and ended at 18:15. It began with a survey lecture of 90 minutes by Eyal Goren, which provided an overview of the structure of such varieties and the most interesting aspects of their arithmetic. This was followed by a series of background lectures given by Shervin Shahrokhi-Tehrani, Dylan Attwell-Duval, and Zavosh Amir-Khoshravi on Hilbert modular forms and cohomology, Chern numbers of Hilbert modular varieties and integral models, respectively.

The afternoon program consisted of three hour long lectures on more advanced topics, Fritz Hoermann on toroidal compactifications, John Voight on computing Hilbert modular forms and Henri Darmon on algebraic cycles on Hilbert modular varieties. This series of lectures provided a beautiful overview of the field, and, as in the first workshop, the contributions of the graduate students were excellent. The day's lectures were followed by a Chinese banquet, which continued the fostering of ties, both mathematical and social, between the two communities.

The Sunday program started at 9:00 and ended in the early afternoon. It consisted of three 55 minute lectures, given by Jayce Getz, on his joint work with Mark Goresky, Kumar Murty, on Tate conjectures and Steve Kudla, on arithmetic special cycles and quartic fields (a survey of recent work of Howard and Yang). These lectures provided a glimpse of deep recent results and, perhaps most importantly, highlighted the many interesting open questions that remain.

The workshop was very successful and its participants are waiting with anticipation the 3rd workshop to be held at the Fields Institute in October 7-9, 2011.

Stephen Kudla (Toronto)

Workshop on Group Actions, Generalized Cohomology Theories and Affine Algebraic Geometry

April 22-24, 2011, Held at the University of Ottawa

Organizers: Daniel Daigle and Kirill Zainoulline (University of Ottawa)

One way to study an algebraic variety X is to look at the embeddings of the affine line A^1 into X . In recent years, two groups of researchers have been doing this, using very different methods. Affine algebraic geometers are interested in algebraic varieties which “resemble” affine spaces A^n (and hence admit an abundance of embeddings of A^1). Here, some of the central questions revolve around the Cancellation Problem (*when is it the case that $X \times A^1 \cong Y \times A^1$ implies $X \cong Y$?*) and the study of the actions of the algebraic group G_a on varieties. The other group of researchers is interested in homotopical and homological methods related to the ongoing project to develop an A^1 -homotopy theory (a homotopy theory in which A^1 plays the role of the unit interval) and to use that theory to classify varieties by homotopy equivalence.

The purpose of the workshop was to bring together specialists and young researchers in these two areas. There were about 30 participants from Canada, the United-States, Switzerland, and Germany, and approximately half of them were graduate students and postdocs.

The workshop featured two introductory lectures aimed at graduate students on “ A^1 -contractibility and topological contractibility”}, by Aravind Asok (USC), and two introductory lectures on “Cancellation”, by Peter Russell (McGill). These lectures were highly appreciated and generated lively discussions and questions between the two groups. Also, the lecturers were kind enough to make lecture notes available.

In addition to the introductory lectures, four talks were given by senior researchers (B. Doran (ETH Zürich), G. Freudenburg (Western Michigan), R. Jardine (Western Ontario), and L. Makar-Limanov (Wayne State)), and four talks by postdocs and Ph.D. students A. Maharana (McGill), J. Malagón-López (Ottawa), L.-F. Moser (München), and K. Palka (UQAM)).

Guelph Biomathematics and Biostatistics Symposium – Climate Change and Ecology: A Mathematical and Statistical Perspective

April 28, 2011, Held at the University of Guelph

Organizers: Marcus Garvie and Julie Horrocks (University of Guelph)

It is generally acknowledged that humanity's transformation of the earth has increased the concentration of greenhouse gases, thereby causing climate change. Climate change is likely to change the frequency of extreme weather events, cause global warming, and lead to extensive changes in many ecosystems. Global climate change is a central issue in ecology, and it is important to assess how anticipated changes might affect biodiversity, food webs and natural resources. The biodiversity impacts of climate change are manifest for example in altered phenology, population density and community structure. Changes in species' geographical distributions have also been detected. Changing ecosystems have the capacity to strongly affect human welfare. For example, the distribution and ecology of several species of pests and diseases of great significance to human and animal welfare, agriculture, fisheries and forestry, are strongly influenced by climatic factors. The complexity of climatic systems makes any predictions and potential mitigating strategies difficult and there is room for uncertainty. In order to ensure that our ecosystems provide the services that society demands, we must be able to predict how ecological communities will respond to global climate change, and in turn how changes in community composition will affect ecosystem services. The focus of this symposium was the mathematical and statistical methodology that will play a crucial role in dealing with such problems. For example, Climate Envelope Models have been used to predict the distribution of species under current, past, and future climatic conditions by inferring a species' environmental requirements from localities where it is currently known to occur.

The aim of the symposium was to provide exposure to various mathematical and statistical techniques used to model and analyze the impact of climate change on the

environment. There were some 55 confirmed participants, mainly from Canada and the United States, with additional participants registering for the day. Approximately half of the participants were graduate students and postdocs. Financial support for the symposium was provided by the Fields Institute and also the Department of Mathematics & Statistics at the University of Guelph.

The symposium was keynoted by two invited lectures, including the Gordon C. Ashton Memorial Biometrics Lecture. The first keynote speaker, James V. Zidek (Department of Statistics, University of British Columbia) gave the Gordon C. Ashton Memorial Biometrics Lecture. This was an exciting talk in the area of agroclimate risk management with applications to prediction of the bloom dates of perennial crops in the Okanagan region of British Columbia. The second keynote speaker was Marie-Josée Fortin (Department of Geography, University of Waterloo). She delivered an exciting talk presenting how statistical models and dynamic species distribution models can be used to study species range shifts.

In addition to the keynote speeches, there were also seven excellent contributed talks.

One of the exciting aspects of this symposium was the opportunity for researchers from various disciplines (e.g. Ecology, Mathematics, Statistics, and Geography) to share different perspectives on Climate Change. This unusual mix of researchers led to some very lively discussions between the various groups.

Workshop on Wave Breaking and Global Solutions in the Short-Pulse Dispersive Equations

May 2-5, 2011, Held at the Fields Institute

Organizers: Dmitry Pelinovsky (McMaster University)

The nonlinear wave equations with low-frequency dispersion such as the short-pulse equation and the Ostrovsky-Hunter equation possess different scenarios in the evolution of smooth initial data that depend on the initial norm. For smaller initial norms, global solutions may exist, which disperse away via wave scattering. For larger initial norms, wave breaking may occur, when the solution remains bounded but the wave slopes become infinite. An interesting feature for many equations of this class is the solvability via inverse scattering, the existence of an infinite number of conserved quantities, and the presence of exact solutions for solitary waves and modulated pulses (breathers).

The purpose of the workshop was to bring together specialists both from the analysis and the application sides of the topic. The workshop initiated collaborations between applied mathematicians, who are involved with the actual modeling of dispersive wave equations, and more pure analysts, who are interested in the analytic solutions of these equations. There were about 30 participants from Canada, the United States, Brazil, France, and Germany, of which approximately half were graduate students and postdocs.

The workshop featured lectures of experts in the field such as A. Himonas (University of Notre Dame), J. Hunter (University of California), N. Kutz (University of Washington),

Z. Qiao (University of Texas - Pan American), G. Schneider (University of Stuttgart), A. Stefanov (University of Kansas), and C.E. Wayne (Boston University). One day of the workshop included talks by six graduate students from University of Washington, City University of New York, University of Kansas, and McMaster University.

Ontario Combinatorics Workshop

May 6-7, 2011, Held at Ryerson University

Organizers: Anthony Bonato and Peter Danziger (Ryerson University)

The field of combinatorics is particularly strong at universities in Ontario – at Brock, Carleton, Guelph, McMaster, Ottawa, Queens, RMC, Ryerson, Toronto, Trent, Waterloo, and York. The main purpose of the Ontario Combinatorics Workshop (OCW) is to bring together graduate students studying combinatorics from Ontario and beyond to present their research, network with other graduate students, and attend lectures by leading researchers in their field. The 19th OCW saw a record attendance of about 50 participants, along with a record number of contributed talks by graduate students and post-docs. Financial support of the participants was provided by the Fields Institute, and catering for the event was provided by the Department of Mathematics at Ryerson.

There were three excellent plenary lectures – *Spatial models for virtual networks* by Jeanette Janssen (Dalhousie), *Optimizing an imperfect tournament* by Brett Stevens (Carleton), and *The Turan Problem, theory and applications* by Jacques Verstraete (UC, San Diego) . These lectures were aimed at a general combinatorial audience, and generated much interest and discussion.

The Peter Rodney Memorial book prize was awarded to Craig Sloss (Waterloo) for the best presentation by a student at the conference.

Sage Days

May 2-6, 2011, Held at Acadia University

Organizers: Eva Curry (Acadia University) and Hugh Thomas (University of New Brunswick)

Sage is an open source mathematical software package which is intended to duplicate and extend the functionality of programs such as Maple and Mathematica, on an open source model. It is a very useful tool for researchers in a number of areas, providing a common interface to specialized software packages such as GAP and Pari. As well, a growing number of resources for using Sage in the classroom are available, including an open content linear algebra textbook (by Rob Beezer of the University of Puget Sound).

Sage Days workshops have been held around the world, and focus simultaneously on introducing new users and developers to Sage, and bringing together expert developers to work on specific development goals. Days 30 followed on from a Sage Days workshop

held at the Fields Institute in May, 2010, and focused on two areas of combinatorics (Schubert calculus and cluster algebras) and ergodic number theory (multidimensional digit representations and number systems). This was the first Sage Days workshop to be held in Atlantic Canada.

Presenting at the workshop were Franco Saliola (UQAM, formerly a Fields Postdoctoral Fellow), Nicolas Thiéry (Université Paris Sud), Florent Hivert (Université de Rouen), Anne Schilling (University of California Davis), Jason Bandlow (University of Pennsylvania), and Anders Buch (Rutgers University). Many students from Atlantic Canadian universities attended, as well as some students, postdocs, and faculty from farther afield. Chris Berg (Fields Institute Postdoctoral Fellow, participation funded by Fields Institute) and Francis Bischoff (UNB) jointly won the Best First Contribution Prize for the week for their implementation of k -Schur functions in non-commutative variables and jeu de taquin for d -complete posets (respectively). Carolina Benedetti (York University, participation funded by Fields Institute) implemented quantum Grassmanian posets which play a role in her doctoral work. Nicolas Thiéry, Florent Hivert, and organizer Eva Curry were also able to implement a general method for enumerating points in the integer lattice with bounded l^p norm, an important step toward implementing faster algorithms for generating digit sets and finding neighbors of self-affine tiles arising from number systems. A list of project worked on during the week can be found at wiki.sagemath.org/days30_projects. Student submissions for the Best First Contribution Prize are listed at wiki.sagemath.org/days30_prize

The organizers would like to acknowledge the support of the Fields Institute, AARMS, Acadia University, and the University of New Brunswick.

Ottawa-Carleton Discrete Mathematics Days

May 13-14, 2011, Held at the University of Ottawa

Organizers: Jason Z. Gao (Carleton), Mike Newman (Ottawa)

There were forty participants from around Ontario and Eastern Canada as well as from further afield.

In spite of a wide variety of topics, the meeting had a nice feeling of cohesion.

Among the invited speakers, Ed Bender (UC, San Diego) spoke about asymptotic properties of locally restricted compositions. One classic example is that of the Carlitz compositions which are compositions with distinct adjacent parts. Under some mild recurrent conditions, it is shown that many interesting parameters of locally restricted compositions, such as the number of parts of a given size, the number of distinct parts, and the maximum part size, all satisfy some well-known law. Some future directions in this area were also given.

Leonard Soicher spoke about semi-Latin squares, which generalize mutually orthogonal Latin squares. He explored the relationships between these objects and design theory, and different measures of optimality. For instance, a block design arising from semi-

Latin square can be shown to be “almost” as good as a block design derived from a putative set of three MOLS of order 10. He also established a particular kind of optimality for uniform semi-Latin squares.

Jim Geelen spoke about a new characterization of graphs within binary matroids. While this is not the most efficient characterization of graphic matroids known, it gives a very natural characterization in terms of a system of linear equations over $\text{GF}(2)$.

Wendy Myrvold spoke about the attempt to find three (or more) mutually orthogonal Latin squares of order 10. She explored the theoretical approach as well as outlining computational approaches and their limitations, and outlined future directions.

Bill Martin ended the conference with a wide exploration of the newer uses of coding theory, including applications to numerical integration, random bit generation, biometrics and computational complexity theory.

A lively group of students and postdocs also participated, some of whom had been associated with the Ottawa-Carleton group in the past.

Robert Bailey spoke on resolving sets for incidence graphs, Andrea Burgess on generalized packing designs, Andras Farago on results on path optimization – finding the shortest path in a graph subject to other constraints, Nevena Francetić on covering arrays with row limit, and Graeme Kemkes showed how cop-win graphs almost always have a universal vertex. The youngest speaker was Andrew MacFie, an undergraduate student who spoke on new results on counting words with respect to the number of occurrences of a given pattern. Ben Seamone spoke on graph colourings derived from edge weightings, Craig Sloss on the (p,q,n) -dipole problem and a join-cut approach to it.

Many of these talks aroused interest and generated discussion among the participants.

Conference on Connections in Geometry and Physics (GAP 2011)

May 13-15, 2011, Held at the Fields Institute

Organizers: Marco Gualtieri (University of Toronto), Spiro Karigiannis (University of Waterloo), Rob Myers (Perimeter Institute), Ruxandra Moraru (University of Waterloo), McKenzie Wang (McMaster University)

The third “Connections in Geometry and Physics” conference took place at the Fields Institute from May 13, 2011 to May 15, 2011. The conference received support this year from the Fields Institute, the Perimeter Institute, the Department of Mathematics of the University of Toronto, and the Faculty of Mathematics of the University of Waterloo. The organizers of the conference, Marco Gualtieri (Toronto), Spiro Karigiannis (Waterloo), Ruxandra Moraru (Waterloo), Rob Myers (Perimeter Institute), and McKenzie Wang (McMaster), welcomed over eighty participants from all over the world to the meeting. In addition to a good mix of senior and younger researchers, the participants included also a large number of graduate students from Canadian universities.

The goals of this yearly conference are to foster interaction and cooperation between geometers and mathematical physicists, to highlight significant international developments in the two fields, and to support the research and training activities of Canadian researchers, their postdocs, and graduate students. Since the first conference, the organizers have selected for each year three topics that help to focus (but not constrain) the conference activities. This year the topics were: advances in Floer theory, geometric flows, and the AdS/CFT correspondence. For those who have not followed this yearly conference closely, the topics for 2010 were mathematical general relativity, gauge theory, and mirror symmetry, and those for 2009 were elliptic and parabolic equations in geometry, the geometry and topology of moduli spaces, and structures in symplectic geometry.

The somewhat intensive schedule over three days of the 2011 conference included twelve hour-long lectures by leading experts working in the three topic areas and seven half hour talks by postdocs on their own research. The atmosphere of the talks was reasonably relaxed and included numerous questions and comments from the audience, some of which came from student participants.

In the area of symplectic Floer theory, Octav Cornea (University of Montreal) reported on new developments in the study of Lagrangian cobordisms and their relation with decompositions in Fukaya categories. François Lalonde (University of Montreal) talked about properties and constructions of weakly exact Lagrangian submanifolds and their relationship with gluing theorems in symplectic geometry and quantum homologies. New filtrations in singular instanton knot homology and their applications were explained by Tom Mrowka (MIT). Lagrangian correspondences and their natural appearance in a functorial setting in extended Fukaya categories were discussed by Katrin Wehrheim (MIT).

There were three talks on geometric flows. John Lott (Berkeley) presented new results regarding the long-time behaviour of the Ricci flow in 3-dimensions and indicated many open questions in this area. André Neves (Imperial College) reported on his work on the prevalence of singularities in using the mean curvature flow to produce special Lagrangian manifolds in Calabi-Yau manifolds. Natasa Sesum (Rutgers) gave a survey and a comparison between the properties of Ricci and Yamabe solitons.

Robert McCann (Toronto) demonstrated the power of ideas from differential geometry, optimal transport and nonlinear PDEs by presenting new uniqueness and stability theorems for the multidimensional version of a famous problem in economic theory solved by Mirrlees and Spence regarding optimal pricing strategy by a monopolist who has only statistical information about the preferences of anonymous buyers.

An important mathematical aspect of the AdS/CFT correspondence is the study of conformally compact Einstein spaces. Michael Anderson (Stony Brook) gave a survey on the Dirichlet problem for Einstein metrics, presenting various results on existence and uniqueness. Robin Graham (University of Washington) used conformal structures to construct new examples of pseudo-riemannian manifolds with split G_2 holonomy. On the physics side, Pedro Vieira (Perimeter Institute) reported on certain exact computations of structure constants and scattering amplitudes in the AdS/CFT correspondence. Aspects of

a conjectured duality between Vasiliev's higher spin gauge theory and vector models were presented by Xi Yin (Harvard).

The shorter talks by postdoctoral fellows likewise covered many interesting topics. These included Floer theory of cleanly intersecting immersed Lagrangians (Ken Chan, Waterloo), new Einstein metrics on associated 3-sphere bundles over Fano Kähler-Einstein manifolds (Dezhong Chen, Toronto), cylindrical contact homology of universally tight sutured solid tori (Roman Golovko, Montreal), extremal Kähler metrics on projective bundles and stability (Hongnian Huang, CRM), a partial compactification of the moduli space of the Vafa-Witten equations (Ben Mares, McMaster), Legendrian knots and contact structures (Sinem Onaran, Waterloo), and CFT correlation functions as AdS scattering amplitudes (João Penedones, Perimeter).

Throughout the conference, the excellent staff of the Fields Institute maintained a steady supply of refreshments and snacks, and saw to it that the visitors from far away were well-taken care of. They also organized a wonderful reception for the conference participants.

The organizers hope that the Geometry and Physics (GAP) conference will become a regular event in the Canadian mathematical calendar, one in which the participants continue to enjoy high level but informal interactions between geometers and physicists from Canada and abroad. Especially with regard to graduate student participants, we hope that they come away energized, with new ideas and perspectives that enrich their research programs, and with new contacts and collaborations that will benefit their chosen careers.

Conference on Analysis of Survival and Event History Data

May 16-19, 2011, Held at the Centre de Recherches Mathématiques, Montréal

Organizers: Richard Cook (Waterloo), Jerry Lawless (Waterloo)

There were about 70 participants at this workshop, coming from Canada, the United States, the United Kingdom, France and Norway. The objectives were to bring together leading researchers in survival and event history analysis to discuss recent advances, current challenges and areas requiring new methodology and theory. Many of the world's top people in the field presented talks and a wide range of important topics were addressed.

Much of the existing theory and methodology for survival and event history analysis was developed over the past 50 years in response to scientific problems arising in fields such as economics, engineering, medicine, public health and the social sciences. Likewise, new needs and challenges arise constantly from these areas and from newer fields such as genetics and information technology. Day 1 of the workshop was designed to profile high impact studies in important areas of public health and biomedicine. Subsequent sessions on days two to four focused more on specific statistical issues pertaining to design, modelling and analysis, discussed in a wide range of scientific contexts.

Keynote presentations on Day 1 were given by Ross Prentice (Fred Hutchinson Cancer Research Center, Seattle), Jack Kalbfleisch and Robert Wolfe (University of Michigan), Danyu Lin (University of North Carolina, Chapel Hill) and Lyle Palmer (Ontario Institute for Cancer Research). Prentice discussed challenges arising from the Women's Health Initiative, which includes both randomized and observational cohort studies on health risks in postmenopausal women. As a Principal Investigator of this extremely important study, he has developed new methodology and published numerous articles on new statistical challenges that have arisen. The talk highlighted current needs related to the assessment of high-dimensional biomarkers, the monitoring and analysis of multiple outcomes, and the assessment of therapeutic or dietary interventions, all of which must be studied in the presence of imperfect measurement processes. The talk by Kalbfleisch and Wolfe discussed methods for monitoring outcomes associated with medical procedures. For example, it is commonplace to monitor outcomes in organ transplant recipients, patients receiving knee or hip replacements, or patients undergoing cardiac surgery. This is done to assess the effectiveness of strategies for managing waiting lists, intervention effects, and the quality of care provided by different facilities, each of which factors into cost-benefit analysis. The speakers focused on the important problem of assessing facilities while making adjustment for the varying distribution of risk factors in individuals that different facilities treat. Danyu Lin spoke next on challenges in survival analysis arising from genetic studies in which data are missing for many individuals. This occurs when only a portion of the individuals involved can be genotyped because of the cost involved, and because individuals are genotyped only at specific locations on their genome. Finally, Lyle Palmer spoke about the Ontario Health Study, a recent initiative which is attempting to build a large voluntary cohort of individuals to be followed from recruitment over their remaining lifetimes, and whose information can be linked to administrative medical records. This raises many new challenges for analysis because of the potential richness of the data but also because it will be necessary to assess potential biases arising from the voluntary nature of study participation and the accuracy of different types of information to be requested. Day 1 concluded with the second Aisenstadt Lecture from the Aisenstadt Chair holder James Robins of Harvard University, followed by a cocktail reception. A discussion of his talk is given elsewhere in this report.

The morning session on day 2 was devoted to the topic of joint models for longitudinal and event history data. This area is increasingly important as longitudinal life history studies collect more and more data on time-varying variables along with data on specified events. Biomarker data, disease risk measures, and other time-varying covariates, for example, are routinely collected on individuals, in addition to data on events such as disease onset or recurrence. Talks in this session were given by Peter Diggle (Lancaster University, U.K.), Joseph Hogan (Brown University) and Jeremy Taylor (University of Michigan). Between them they discussed problems arising in the treatment of persons suffering from renal disease, prostate cancer and infection with the Human Immunodeficiency Virus (HIV). Challenges highlighted included the need to deal with very heterogeneous longitudinal marker profiles, the fact that these markers are measured only intermittently on each individual, and the difficulty of assessing the relationship between treatment effects on marker values to treatment effects on clinical events. The

afternoon session on Day 2 dealt with problems associated with incomplete or mismeasured covariates that are potentially informative for health-related events. Many examples of this were given in the Day 1 talks. Rod Little (University of Michigan) discussed likelihood and Bayes estimation methods for incomplete data and Joe Ibrahim (University of North Carolina at Chapel Hill) presented diagnostic methods for assessing case influence and model fit in the presence of missing data. Donna Spiegelman (Harvard University) discussed risk set calibration methods for handling measurement error, motivated by problems in the measurement of dietary and environmental risk factors for human health.

The two sessions on Day 3 dealt with survival time models. The morning session focused on predictive models for lifetime events, which are widely used to provide risks (probabilities) of disease occurrence according to an individual's age and other risk factors. Tianxi Cai (Harvard University) discussed challenges arising from the availability of new biological and genetic markers and illustrated new methodology on a risk prediction model for rheumatoid arthritis. Richard Simon (National Cancer Institute, U.S.A.) discussed the use of very high-dimensional genomic markers and the evaluation of survival risk models based on them. Patrick Heagerty (University of Washington) presented graphical and analytical methods for characterizing the predictive power of biomarkers using measures related to the area under ROC curves. The afternoon session focused on models and methods for multivariate lifetime data. Rebecca Betensky (Harvard University) discussed ways of handling truncated lifetime variables due to constraints imposed by the sampling or observation of individuals in a study. Li Hsu (Fred Hutchinson Cancer Research Center, Seattle) considered the analysis of studies in which lifetimes for related family members are collected. Yi Li (Dana Farber Cancer Institute, Boston) discussed the analysis of multivariate lifetime data when the number of covariates exceeds the number of individuals or units in a study; this situation has become very common with the collection of large amounts of genomic data on relatively small numbers of individuals, as discussed earlier in the day by Richard Simon.

The morning session on Day 4 considered the topic of response-biased sampling, which is an important feature in many epidemiology studies in which genetic factors or other expensive measurements can be taken on only a subset of individuals of interest. Ornulf Borgan (University of Oslo) gave a comprehensive overview of nested case-control and case-cohort study designs and associated estimation methodology. Nilanjan Chatterjee (National Cancer Institute, U.S.A) reviewed recent developments for multivariate analysis of disease onset times for families with high-risk genetic variants. Alice Whittemore (Stanford University) discussed two-stage studies for validating individual risk models and illustrated the methodology on models for ovarian cancer. The final session on Thursday afternoon addressed issues in the analysis of complex life history processes. Many examples of the complexity of processes associated with health and biomedicine had been seen in earlier talks and a nice bookend to the Workshop was provided by the talks in this session. Stephen Cole (University of North Carolina at Chapel Hill) considered the increasingly popular marginal structural models approach to estimation, drawing for discussion on the effects of antiretroviral therapy on the incidence of AIDS and death in HIV-infected persons. Somnath Datta showed how to

estimate various features of a multistate model non-parametrically. Such models are widely used in modelling and analyzing states associated with health, employment, parenthood, education and other aspects of human lives. Doug Schaubel ended with an excellent talk on estimating the effect of a time-varying factor when censoring (end of follow-up) of an individual may be non-ignorable. He illustrated the issues and some proposed methodology by considering the selection of wait-listed persons with severe liver disease for a liver transplant.

Feedback on the Workshop has been extremely positive, with comments from several people that it was one of the most informative meetings that they had ever attended. Graduate students, postdoctoral fellows and more senior researchers were all able to learn a great deal about the methodology, theory and emerging challenges in this key area of statistical science, and thanks go to the speakers for their excellent presentations.

Workshop on Computational and Analytical Mathematics

→ See end of document

Southern Ontario Statistics Graduate Students Seminar Days

May 18 – 22, 2011, Held at the University of Western Ontario

Organizers: Jonathan Lee, Maggie Chu, W. John Braun (UWO)

This event, built on the Southern Ontario Statistics Graduate Student Seminar Days (SOSGSSD) is hosted annually by a university in Southern Ontario. Since 2000, the school has been held in Southern Ontario with the exception of the two year period 2008-2009. Normally, the SOSGSSD is a one or two day meeting for graduate students in the area of statistics and biostatistics, designed to gather and present their research to each other. The seminar days offer a networking opportunity for graduate students which would otherwise be unavailable.

This year, the University of Western Ontario hosted the school, but extended its reach nationally. The event was attended by 50 students representing 17 universities across Canada, and featured 16 student presentations over a two day period, covering a wide range of topics in statistical research ranging from biostatistics to financial mathematics to statistics and the environment.

A keynote presentation was given by Patrick Brown from Cancer Care Ontario and the University of Toronto on “Disease mapping with aggregated spatial data”. The address featured several issues that arise when modelling health data collected at different spatial resolutions. Methods for reconciling and modelling such spatially “interval-censored” data was the main focus of the talk.

The keynote address served as motivation for the subsequent 3-day summer school on spatial statistics. Spatial statistics has applications in the modelling of many phenomena in the sciences, such as seismology, epidemiology, ecology, forestry and geography. The

instructors for the summer school were Patrick Brown and Virgilio Gomez-Rubio who traveled to the event from the University of Castilla La-Mancha, Spain.

This summer school was a follow-up to the MITACS/GEOIDE Summer School on Climate Modeling and Spatial Statistics held in 2010 at Simon Fraser University. The topic covered this year was Spatial Statistics for Non-Gaussian Data. It consisted of three days of lectures supplemented with hands-on lab sessions using R for analysis as well as data visualization.

This event was made possible through funding from: GEOIDE, the Fields Institute, MITACS, Research Western, UWO's Society of Graduate Students, UWO's School of Graduate and Postdoctoral Studies, and the Southern Ontario Regional Association chapter of the Statistical Society of Canada.

Waterloo Workshop in Computer Algebra (WWCA 2011)

SNAP Math Fair Conference

May 27, 2011, Held at the Fields Institute

Organizer: Tanya Thomson (ThinkFun, Inc.)

Friday, May 27th, 2011, SNAP Mathematics Foundation ran their fifth annual conference on SNAP Math Fairs at Fields Institute. Over 70 educators from across Ontario attended this informative event. Since its inception 14 years ago, SNAP Math Fairs have ignited the mathematical minds of students through the use of classic puzzles and problems. Students solve these interesting problems and then build an interactive, hands-on project which includes a model to help the passers-by solve the problems. SNAP math fairs provides an opportunity for elementary school communities to gather together to celebrate mathematics!

Tanya Thompson, a former teacher and currently the head of Inventor Relations for ThinkFun, Inc. and a board member of SNAP, once again organized the conference and presented details about SNAP Math Fairs. Tiina Hohn, a math instructor at the brand new Grant MacEwan University in Edmonton and a member of the SNAP Mathematics Foundation from the beginning, got down to the business of problem solving through demonstrations and group activities that are appropriate for using in a Math Fair. Ivars Peterson, Director of Publications and Communications at the Mathematical Association of America in Washington, D.C., gave a compelling presentation on the Mobius Strip. Ron Lancaster, a Senior Lecturer in Mathematics Education at the Ontario Institute for Studies in Education of the University of Toronto, gave an interesting talk on what happens to numbers when an operation is done repeatedly. Bill Ritchie, the co-founder and C.E.O. of ThinkFun, Inc. and a board member of SNAP, shared his how using mind-challenging games can be used to teach complex mathematical ideas. Judith Rioux-Wilson, a teacher at St. Catherine Catholic Elementary School with the P. V. N. C. Catholic School Board in Peterborough, spoke about her strategies, her expertise and her knowledge on how to use the momentum and enthusiasm of children and staff to organize and lead an effective Math Fair that is proven through data to improve engagement,

confidence and scores in Math. Jennifer Wyatt, a teacher at Havergal College currently on leave to the Ministry of Education as an Education Officer, talked about her experiences with Math Fairs at Havergal. Clare Mahon, the Program Director of a Toronto-based consultation firm called The Learning Link, explored the rationale for integration of math games and problems as a means of addressing a highly demanding math curriculum. Tyler Somer, a former mathematics teacher and co-writer of the grade nine national mathematics competition (Pascal) at the CEMC/University of Waterloo, presented an intricate look at the classic problem Towers of Hanoi. Elaine Polsinelli, a teacher at Windfields Jr. High School in Toronto, shared her experience of putting on her SNAP Math Fair.

The main highlight of the conference was a SNAP Math Fair presented by over forty K-8 students of St. Catherine Catholic Elementary School in Peterborough. These students, under the guidance of their teacher Judith Rioux-Wilson, astounded the conference participants with their excitement and knowledge of their math fair projects. This school has received high praise and approval from their Superintendents and the Director of Education. The participants were able to witness first-hand the many benefits to the students of taking part in a SNAP math fair.

Many thanks are expressed to the sponsors of the conference. SNAP Mathematics Foundation (www.mathfair.com), ThinkFun, Inc. (www.thinkfun.com) and the Fields Institute.

The SNAP Math Fairs conference at Fields was an outstanding success. Educators learned how to inspire their students through creative, interactive mathematical puzzles and problems. They saw how students took ownership of these age old puzzles and gained confidence in many areas of problem solving. Since the launch of SNAP Math Fairs in Ontario just over 6 years ago, many schools are now participating in SNAP math fairs and this movement continues to grow stronger each year!

CanaDAM 2011 (Canadian Discrete and Algorithmic Mathematics Conference)
May 31 – June 3, 2011, Held at the University of Victoria

Organizers: Pavol Hell (Simon Fraser), Odile Marcotte (UQAM, CRM), Ortrud Oellermann (Chair, Winnipeg), David Pike (Memorial), Bruce Richter (Waterloo), Frank Ruskey (Victoria)

This was the third instance of this conference which is held biennially in odd numbered years and alternates with the SIAM Conference on Discrete Mathematics held in even

numbered years. This series of conferences has very quickly become internationally known and respected in the field of Discrete Mathematics.

The CanaDAM 2011 meeting had 307 registered participants of which 129 were students. At least 19 different countries were represented on the list of participants. A great deal of credit for the success of the conference goes to the Program Committee chaired by Nick Wormald from the University of Waterloo and the Local Arrangements Committee chaired by Gary MacGillivray from the University of Victoria. More detail on the various organizing committees can be found on the conference web page canadam.math.ca/2011.

The strength of the conference is of course directly related to its scientific program. The program committee under the leadership of Nick Wormald put together an excellent program consisting of 8 plenary talks, 39 invited minisymposia talks, 117 contributed minisymposia talks, and 72 contributed talks. The plenary speakers and the titles of their talks were

Anne Bergeron (UQAM, Canada)
The combinatorial beauty of genome evolution

Sara Billey (University of Washington)
An introduction to k -Schur functions and QSYM

Allan Borodin (University of Toronto)
When is it good to be greedy (in algorithm design)

Chandra Chekuri (University of Illinois, Urbana-Champaign)
Submodular set functions maximization via the multilinear relaxation and dependent randomized rounding

Jacob Fox (MIT)
Intersection graphs, drawings, posets, and separators

Jeff Kahn (Rutgers University)
Thresholds and Expectation Thresholds

Alice Silverberg (University of California at Irvine)
Counting points on elliptic curves, from Gauss to present

Stephan Thomasse (Université Montpellier 2)
Applications of VC dimension for graphs and hypergraphs

In addition to these plenary talks there was a very well received one hour popular lecture on the mathematics of Origami given by Joseph O'Rourke from Smith College. This lecture was preceded by a reception hosted in part by Elsevier.

One of the primary goals of these conferences is to encourage the participation of Canadian graduate students and PDFs. The three Canadian mathematical institutes (CRM, Fields and PIMS) as well as MITACS (Mathematics of Information Technology and Complex Systems networks) each pledged \$8300 towards the support of graduate students and PDFs attending the meeting. In addition to its monetary contributions, the Fields Institute assisted with the design and distribution of the conference poster for CanaDAM 2011. In order to receive financial support graduate students were encouraged to contribute talks. Furthermore, Brett Stevens from Carleton University hosted a problem session devoted to the presentation of research problems appropriate for graduate students. A reception for graduate students followed the problem session. It was especially gratifying that more than 40% of the attendees were graduate students and post doctoral fellows. This solid participation of students and PDFs could not have happened without the generous support of CRM, Fields, PIMS and MITACS.

The CanaDAM meeting now has a permanent 'home' with the Canadian Mathematical Society. The CMS provided all the conference services such as webpage design and maintenance, abstract submission, and processing of registration fees for this year's meeting. In addition to these services the CMS will also provide ongoing financial services support by maintaining a CanaDAM account into which registration fees prior to the conference are deposited. These funds will be transferred to the host institution for the processing of all conference expenses. After the conference expenses have been processed, seed funding for the next CanaDAM meeting (in the amount of approximately \$5000) will be deposited into the CanDAM account at the CMS. The CMS's extensive experience in handling conferences and their online facilities were a tremendous asset in the planning of CanaDAM 2011. Having a permanent on-line home for CanaDAM is particularly beneficial as it will provide continuity to the meetings.

Planning for CanaDAM 2013 is already under way. The executive committee for the next meeting has been struck – its members are Frank Ruskey (University of Victoria), Odile Marcotte (UQAM, CRM), David Pike (Memorial), Gary MacGillivray (University of Victoria), Brett Stevens (Carleton University), and Lorna Stewart (University of Alberta). The host institution for CanaDAM 2013 will be Memorial University in St. John's, Newfoundland, and David Pike will be the local arrangements committee chair.

International Workshop on Perspectives on High-dimensional Data Analysis

June 9-11, 2011, Held at the Fields Institute

Organizers: S. Ejaz Ahmed (chair), University of Windsor Peter X. K. Song, University of Michigan Mu Zhu, University of Waterloo

This workshop attracted many international participants from USA, France, and other countries, with a variety of topics covering theory, methodology and applications. Many participants at end of the workshop had indicated their interest to take part in a future workshop of a similar type to further discuss research progress in these research areas.

Many modern scientific investigations require the analysis of high dimensional data. Examples include genomic and proteomic data, spatial-temporal data, network data, and many others. Simultaneous variable selection and parameter estimation play a central role in such investigations. There is now an immense literature on variable selection, and penalized regression methods are becoming increasingly popular. Much new development has been published in recent years by leading statistical journals. The application of linear regression models for high-dimensional data analysis is a challenging task. Regularization techniques, such as adaptive penalized least-squares, have attracted much attention in the literature. Penalized regression is a technique for mitigating difficulties arising from collinearity and high-dimensionality. This approach necessarily incurs an estimation bias, while reducing the variance of the estimator. A tuning parameter is needed to adjust the effect of the penalization so that a desirable balance between model parsimony and goodness-of-fit can be achieved. Different forms of penalty functions have been studied intensively over the last 10-15 years. Examples include the LASSO and its many variants (such as adaptive LASSO, group LASSO, relaxed LASSO, and so on), the SCAD, the Dantzig selector, and the elastic net, to name just a few. More recently, some of these penalization/regularization techniques have been extended to deal with the estimation of large covariance matrices, and the analysis of complex dependence structures such as networks and graphs.

The purpose of the Workshop is to stimulate research in an informal setting, and to foster the interaction of researchers in the arena of High-dimensional Data Analysis. This workshop hopes to provide a venue for participants to meet leading researchers of this field in a small group in order to maximize the chance of interaction and discussion. The objectives include: (1) to highlight and expand the breadth of existing methods in high-dimensional data analysis and their potential for the advance of both mathematical and statistical sciences, (2) to identify important directions for future research in the theory of regularization methods, in algorithmic development, and in methodology for different application areas, (3) to facilitate collaboration between theoretical and subject-area researchers, and (4) to provide opportunities for highly qualified personnel to meet and interact with leading researchers from countries around the world.

The Workshop was endorsed by the Statistical Society of Canada and was held just prior to the Statistical Society of Canada's annual meeting in Wolfville, NS (June 12-15, 2011). There were about 64 participants from Canada, the United States, and France, and approximately 17 of them were graduate students and postdocs. It had a good mixture of young and senior researchers.

The Workshop featured three keynote talks by, Rudy Beran (University of California-Davis), Jiahua Chen (University of British Columbia), and Xihong Lin (Harvard University). Each speaker eloquently presented challenges and opportunities emerging from this new statistical research arena. Further, participants enjoyed the lively and provoking discussions after the talks which continued during the lunch and coffee breaks. A catered lunch at Fields provided ample opportunity for further networking among the participants.

In addition, 25 invited talks were presented by influential researchers on various aspects of High-dimensional Data Analysis and were well received by the audience. Most of presentations had followed with insightful comments and interesting discussions. A poster session was also organized during break/reception times to showcase the recent work of graduate students. This was also well attended. Participants had active exchanges ideas and in-depth discussion on current research activities and future research directions. In summary, several directions for the variable selection and post estimation were highlighted not only by the speakers but also through discussions by the participants. We hope that this workshop conveyed some of the surprises, puzzles and successes of theoretical and computational statistics in high dimensional data analysis.

Workshop on the Mathematics of Extreme Sea Waves: Tsunamis, Rogue Waves, and Flooding

June 13-15, 2011, Fields Institute event held at the University of Toronto

Organizers: Walter Craig (Mathematics & Statistics, McMaster University), Diane Henderson (Mathematics, Pennsylvania State University), Efim Pelinovsky (Department of Nonlinear Geophysical Processes, Institute of Applied Physics, Nizhny Novgorod, Russia), Catherine Sulem (Mathematics, University of Toronto)

I was attending a conference at the American Institute of Mathematics (AIM) in Palo Alto, California on March 11 2011, when news came through of a serious earthquake hitting Japan. It was known within minutes that there was great potential for a serious tsunami, due to the operations of the earthquake and tsunami observations division of the Japan Meteorological Agency, and the Pacific Tsunami Warning Center run by the American NOAA. And indeed within ten minutes the Richter scale 9 earthquake drove waves of over 10 meters (and some reported at up to 50 meters) onto the Japanese coast, overwhelming the coastal defenses against such events. The result was the loss of 20,000 lives, enormous property damage, and a nuclear disaster whose effects continue today, months after the initial events. At the time I was tempted to drive to the California coast to witness the tsunami's arrival some 12 hours after the earthquake (in competition for the Darwin award, as some would say). Several days after, Efim Pelinovsky e-mailed me with the urgent request to act; many facts are known about the dynamics of tsunamis, however many things are not known, including an understanding of their initial conditions and a detailed description of the effects of focusing and dispersion as these waves impact on the coast. As mathematicians interested in wave dynamics in the ocean, we felt a sense of urgency to act, to communicate with the ocean scientists and modelers of ocean waves, and to attempt to address some of the pressing outstanding problems in this field. The subtitle of the NOAA Center for Tsunami Research concisely states these activities as 'Developing methods and tools to reduce tsunami hazard and protect life'. This workshop on extreme ocean waves at the Fields Institute in June 2011 plays the role of a first step in this effort.

Our event was of the character of a 'hot topics' workshop, intended to place mathematicians in touch with physical oceanographers, with the purpose of informing

both communities of the existing challenges, up-to-date methods, and the most important outstanding problems of the topic. Our principal immediate goal was to articulate the most relevant problems in the discipline, and outlining the role that mathematics can play in addressing them. Subsequent to this, we hope to establish deeper collaborations and research links between the two research communities. The immediate reason for organizing this workshop is the recent destructive tsunami that followed the severe earthquake in Japan. In most known cases (but not all), tsunami waves are initiated seismically, they propagate at high speed across oceans, and their impact upon coastlines can be very destructive. Tsunamis are rare events, and because for the most part they are generated by large earthquakes, prediction is very difficult, a science grand challenge problem. In addition to earthquake detection, many other factors come into play in tsunami prediction, including analysis of the mode of ocean floor movement through real-time rapid analysis of seismic data, and detailed local considerations of impact on coastlines, as the destruction caused by a tsunami depends sensitively on the particular topography of the coastline and inshore bathymetry. The two major tsunami disasters of the last 10 years, one caused by the Sumatra earthquake of December 26, 2004 and the very recent Tohoku earthquake in Japan, show that a better understanding of the phenomenon is vital to future coastal development in order to minimize loss of life and destruction of infrastructure.

Mathematically, the dynamics of ocean waves include a number of other natural hazards that are relatively poorly understood, and which are topics of current research. In addition to tsunami waves, there are current research programs on rogue waves that represent an increasing danger to ship traffic as the importance of shipping is increasing in the modern economy, as is the increasing number of large vessels present in the Earth's oceans at any one time. Rogue waves are presumably quite rare, and both their dynamics and the statistics of their occurrence are not well understood. They are difficult to measure accurately or to model in a fluid dynamics laboratory with any expectation of precision. Yet marine accidents due to rogue waves are believed to be the cause of on average ten major ship losses per year. This is therefore a challenge for mathematics and mathematical modelling to play a role in the research effort to understand and to predict the phenomenon. These giant waves were once considered a mariner's myth, however they are now known to exist and to be a rare but significant marine hazard. A history of their modeling consists of a number of controversies, as do attempts at predictions of their statistics. There is in fact one precise scientific measurement of a rogue wave, taken on New Year's Day in 1995 on the Draupner Platform in the North Sea; however for the most part there are either satellite traces picked from ocean wave fields, or anecdotal descriptions from 'the bridge' -- one early such observation appears in the log of Ernest Shackleton, an encounter with an apparent rogue wave during his open boat voyage to seek help for his crew after his ship, the *Endurance*, foundered after being caught in polar ice.

In any case there is an annual cost in economic terms as well as human life, and it seems a problem to which mathematics and mathematicians have the potential to make important contributions. The phenomenon of rogue wave formation is considered likely to be due to a focusing effect of two oblique wave fields; this is an effect that is enhanced

in the presence of a current running counter to a prevailing wind, and thus it is a possibility that predictions can be made regarding sea conditions under which rogue waves are more likely. It is furthermore considered probable that the phenomenon of a rogue wave is transient, and therefore difficult to detect with certainty. One-dimensional models of Dyachenko and Zakharov show under certain conditions the generation of large amplitude waves from a wave field of substantially lower amplitude. Focusing effects have been studied in numerical simulations of Bateman, Swan and Taylor, using methods developed by Craig and Sulem. It is a field that will benefit from further attention and analysis, and one in which there is the potential benefit from collaborations between the mathematics community and ocean scientists.

Our workshop took place over the days of June 13 -16 2011, hosted by the Fields Institute. Fourteen plenary lecturers gave hour talks, roughly evenly divided between the topics (1) tsunamis and tsunami prediction and warnings, and (2) rogue wave phenomena. Eight of these speakers were practicing mathematicians, while otherwise we had university faculty from the departments of coastal and ocean science, geosciences, and representatives from the Canadian Institute of Ocean Sciences, the US National Oceanic and Atmospheric Administration (NOAA), the Russian Academy of Sciences, and the Australian Meteorological Office. The first lectures of the day were planned as overview talks, given by senior specialists in the topic, for the purpose of calibrating the background of the participants. These were followed by more focused and technical talks, on a wide variety of topics relevant to the research area.

The first day was dedicated to tsunami research, with a general overview lecture by H. Segur (Applied Mathematics, University of Colorado), who explained the initial conditions of tsunamis generated by dip-slip seismic events (the most common major events in coastal subduction zones), describing the essentially linear but dispersive evolution of tsunami waves in the open ocean, and then showing film of the pile-up of such waves as they encounter the coast, and their resulting destructive power. This was followed by H. Yeh (Coastal & Ocean Engineering, Oregon State University) who discussed a theoretical limit of nonlinear amplification of a nonlinear wave at oblique incidence to a vertical wall (reminiscent of the tsunami barrier walls constructed at great expense in Japan). D. Greenslade (Bureau of Meteorology, Melbourne Australia) followed with a detailed description of the elements of a tsunami warning system, and in particular the Australian components of the Pacific Tsunami Warning Center. The day was capped by the fascinating and wide-ranging talk of E. Okal (Geophysics, Northwestern University) describing tsunamis in terms of the earth's normal modes, and a variety of unusual and imaginative detection methods based (roughly) on this fact.

The second day of the workshop was dedicated to rogue waves and their mathematical models. E. Pelinovsky (Department of Nonlinear Geophysical Processes, Russian Academy of Sciences, Nizhny Novgorod) gave a wide-ranging survey talk that gave a definition of a rogue wave, described their danger to maritime activities, and gave a context for mathematical models and their statistics. We then heard from G. Pedersen (Mathematics, University of Oslo) who described the phenomenon and the history of nonlinear waves in fjords that are generated by large landslides, and what the Norwegian

geologists are doing to model these waves and to monitor potentially unstable geological formations lying over fjords. The final lecture was by J. Dudley (Institut d'Optiques, Université de Franche - Compté) describing mode equations for rogue waves in a modulational regime, and the special breather-like solutions that these equations admit.

The third and fourth days of lectures featured talks on a wide range of topics involving the dynamics of ocean waves, their mathematical modeling and issues involved in their practical prediction and detection. D. Arcas (NOAA, San Diego) spoke on operational aspects of tsunami modeling and detection, complementing Greenslade's description with the US contributions to the global detection system. M. Onorato (Torino) spoke on the role of currents in generating rogue waves. I. Fine described the Canadian contributions to the tsunami detection network, and the research potential that they have. And O. Bokhove (Applied Mathematics, University of Twente) brought an experimental device to his lecture, which demonstrated beach and shoreline dynamics due to nonlinear wave erosion. D. Dutykh (CNRS, Chambéry) described a beautiful model equation for shallow water dynamics, including the run-up onto the beach, a potentially very useful modeling tool for large-scale tsunami impact studies. J. Gemmrich (Physics, University of Victoria) described a classical statistical approach to predicting the probability of rogue waves from extrapolation from known distributions of sea states. And finally, Ch. Kharif (IRPHE - Université de Marseille) gave a wide-ranging overview of models of extreme sea states, with applications to rogue wave modeling in both two and three dimensions.

We feel that the workshop was a success, and this week spent with non-mathematician colleagues was very valuable both to them and to ourselves. It makes one reflect on the degree to which Canada could put more emphasis and interest in science whose aims are to protect its shores and its shipping. In the mean time we return to our own contributions, guided by what we learned. We are looking forward to a deeper and more broadly construed program on the 'Mathematics of the Earth's Oceans' to take place within the context of the Mathematics of Planet Earth initiative in the year 2013.

Walter Craig (McMaster)

Canadian Undergraduate Mathematics Conference

June 15-19, 2011, Held at the Université Laval

Organizers: Anika Pascale Papillon, Andréa Deschênes, Laurent Pelletier, Dominique Maheux, Jean-Sébastien Lévesque

This year, the CUMC attracted over 160 students (mainly undergraduates), of whom approximately 80 gave talks. There were 5 concurrent lectures happening during each lecture block. The conference also featured eight keynote speakers from Canada and abroad. The main subjects of those talks were pure and applied mathematics, statistics, computer science, physics and finance.

Many ideas and subjects were treated during the conference, but only a few can be described in this report.

At the beginning of the conference, three professors (André Fortin, Pamela Gorkin and Frédéric Gourdeau) gave tips about how to give a good talk. Many participants had never given a scientific talk and the CUMC is the perfect event at which to begin – one of the main objectives of the conference is to give undergraduate students the opportunity to give a mathematical talk on a topic of their choice. For many of us, our future job will be teaching and sadly, we don't usually have the chance during undergraduate courses to gain experience in giving talks.

Another keynote speaker, Yvan Saint-Aubin, talked about randomness and conformal invariants, which are advanced subjects for undergraduate students. The most impressive aspect of this presentation was the contact with the audience – some students were asked to come in front to answer questions. It kept the presentation quite dynamic, which is not always the case in classes or talks. With a touch of humour, Saint-Aubin helped us understand the problem solved by S. Smirnov, the winner of a Fields Medal in 2010. It was a reminder of how popularization is important and effective in the understanding of new ideas, especially in mathematics.

At the end of the event, Frederick Rickey gave a talk on the history of the Fundamental Theorem of Calculus. We found out how the definitions of the integral changed in the last two centuries. I could have never learned such a thing in any optional courses during my undergraduate studies. As mentioned during the talk, it is helpful to learn the history of a concept to be able to explain it fully to students. I think the history of mathematical ideas could be taught (at least a bit) in our regular courses to understand the intuition behind those ideas. This is an example of what the CUMC is all about: learning new (or old) aspects of mathematics.

These are just a few examples of the excellent presentations the participants gave during the CUMC. Finally, I have to mention that the quality of the presentations was astonishing and the subjects were quite varied. Every participant could find something to suit him/herself, either to learn about a totally new subject in mathematics or to get the hang of an advanced idea in their own domain.

Dominique Maheux(Laval)

North American GeoGebra Conference

June 17-18, 2011, Held at the Ontario Institute for Studies in Education (OISE),
University of Toronto

Organizers: Dragana Martinovic (University of Windsor), Zekeriya Karadag (Tufts University), Doug McDougall (University of Toronto)

GeoGebra is interactive geometry software for use in educational institutions. In an attempt to engage the communities of mathematicians, mathematics educators, and software developers in discussions of the potential of technology for the learning and teaching of mathematics, the First North-American GeoGebra conference (GeoGebra-NA2010), held on July 28-29, 2010 in Ithaca, NY, laid the foundations for a series of conferences in North America and consequently for this conference in Canada. The idea is to hold annual conferences in the US, Canada and Mexico.

GeoGebra-NA 2011 focused on applications of computer technology in mathematics education from K-16+. In particular, it provided a forum for exploring research, development and application processes in relation to:

1. Teaching mathematics with technology
 - a. Dynamic mathematics in action-educational research and experience
 - b. Applying multiple representations with GeoGebra
 - c. Promoting conceptual understanding of mathematics through explorations.
2. Learning mathematics with technology
 - a. Maximizing effectiveness of the software interface
 - b. Classic, home schooling and informal education
 - c. Bridging the digital divide in access and learning opportunities.
3. Implementation of advanced technologies in mathematics education
 - a. Developing big mathematics ideas through technology use
 - b. Using collaborative spaces to teach and learn mathematics
 - c. Making intra- and inter-disciplinary connections through technology use.

The conference brought together about 30 presenters and participants from Canada, the United States, England, and the Czech Republic. About half of the participants were graduate students or teachers. Financial support for the conference was provided by the Fields Institute and OISE (University of Toronto).

There were two plenary sessions featuring Canadian speakers. The first was *Learning Collaboratively To Meet the Net Generation's Needs: What Can We Learn From the GeoGebra Community?*, by Viktor Freiman, Université de Moncton. The second was on *GeoGebra and the Global Village-Theatre: Realizing the 21st Century Potential of Dynamic Mathematics For/By All*, by Daniel Jarvis (Schulich School of Education, Nipissing University).

The presentations covered technologies such as interactive whiteboards, PC tablets, GeoGebra, Cabri, Geometer Sketchpad and Cinderella, as well as various mathematics disciplines, such as geometry, probability and calculus. The conference was organized in a single track sessions, which allowed for lively discussion and effective exchange of knowledge between all participants. In addition to the plenary talks, there were nine presentations by Catherine Bruce, Rich McPherson and Farhad Sabeti (Trent University), Nenad Radakovic (OISE/University of Toronto, Graduate Student), Linggou Bu (Southern Illinois University), Miranda Tucker (Southern Illinois University, Graduate Student), Petra Surynková (Charles University in Prague, Graduate Student), Carol Carruthers (Seneca College), Margo Kondratieva (Memorial University), Kate Mackrell (University of London, Graduate Student), and Marc Renault (Shippensburg University). One working group on *GeoGebra and Online Collaborative Mathematics*, was organized by Geoffrey Roulet (Queen's University).

The conference proceedings were published on a CD and distributed among the participants [Martinovic, D., Karadag, Z., & McDougall, D. (Eds.)(2011). Proceedings of the Second North American GeoGebra Conference, GeoGebra-NA 2011, June 17-18, 2011, Toronto, ON: University of Toronto. ISBN 978-0-920233-65-8 (CD)].

Fields-MITACS Conference on the Mathematics of Medical Imaging

Mixed Integer Programming (MIP) Workshop

June 20-23, 2011, Held at the University of Waterloo

Organizers: Shabbir Ahmed, Ricardo Fukasawa, Ted Ralphs, Juan-Pablo Vielma, Giacomo Zambelli

Mixed integer programming (MIP) is a subfield of mathematics that seeks to solve decision problems in which some variables are required to take on integer values. Formally, the most common MIP models seek to minimize a given linear objective function over a set of feasible solutions of the form $P \cap (\mathbb{Z}^p \times \mathbb{R}^{n-p})$, where P is a given polyhedron. More recently, more general forms involving nonlinear functions and stochasticity have emerged. Such problems are also known as discrete optimization problems and are a subclass of the broader class of mathematical optimization problems. MIP has a very wide range of applications due to its immense power to model intrinsically discrete decisions, for example, whether or not to open a factory, the number of trucks required in a delivery fleet, the number of people to hire, etc. It has been used extensively in military, commercial, and industrial applications, such as airline scheduling, healthcare, transportation, supply chain logistics and many others. Virtually all large companies make at least some of its decision using this technology and it is hard to underestimate its impact on the world economy.

The 2011 Mixed Integer Programming Workshop (MIP 2011) was the eighth workshop in a series established in 2003. The goals of the workshop series include providing a venue for presentation and discussion of unpublished and cutting-edge results, and foster research collaboration for future development of the field. Talks are by invitation only with at least half by early-career researchers. The remaining speakers are established leaders in the field. The hope is that these leaders will interact with the younger researchers, helping to ensure the health and vitality of the field. Senior speakers are expected to stay for the entire conference. Overall, there is a strong focus on participation by students, post-docs, and young researchers. For this reason, there was no registration fee charged for MIP 2011 and support was offered to select postdocs and students who present their work at the meeting. The funds provided by the FIELDS institute were solely used for this purpose.

The 2011 workshop took place at the University of Waterloo's conference center, located on Ron Eydtt Village on June 20-23, 2011. We had 22 invited speakers (12 early-career, including 5 postdocs) and 24 poster presentations (13 students, 9 postdocs and 2 professors) selected from 37 submissions. We also had 159 registrants for the workshop (92 students and postdocs), most of them from Canada, the United States, Germany, France, Italy and England.

The wide variety of talks and poster presentations covered several of the fundamental topics related to Mixed-Integer Programming. Topics included cutting planes, mixed-integer nonlinear programming, decomposition methods, mixed-integer optimal control, combinatorial optimization problems, applications, symmetry, stochastic optimization

and branching. Our full lineup of speakers and poster presenters can be found at the workshop website: www.math.uwaterloo.ca/~mip2011.

There was plenty of time left for discussion and collaboration between participants. In particular, we would like to highlight several open problems posed by speakers, as well as the discussion session, which entailed a discussion of more general challenges and issues regarding the field and its future.

Overall, given the participants' positive feedback, we feel that the workshop was a success and it achieved its stated goals.

Ricardo Fukasawa (Waterloo)

26th Annual IEEE Symposium on Logic in Computer Science (LICS 2011)

June 21 – June 24, 2011, Held at the Fields Institute

Organizers: Benoit Larose (Champlain Regional College), Matt Valeriote (McMaster)

The IEEE Symposium on Logic in Computer Science (LICS) is an annual international forum on theoretical and practical topics in computer science that relate to mathematical logic in a broad sense. The Symposium is sponsored by the IEEE Computer Society Technical Committee on Mathematical Foundations of Computing, with ACM SIGACT as Technical Co-Sponsor, in cooperation with the Association for Symbolic Logic, and the European Association for Theoretical Computer Science. The LICS General Chair is Rajeev Alur, the LICS Treasurer is Martin Escardo, the Workshop Co-Chairs are Adriana Compagnoni and Maribel Fernandez, and Andrzej Murawski and Stephan Kreutzer are the Publicity Co-Chairs.

Since 1986, LICS conferences have been held on an annual basis in various locations in North America and Europe and this past summer, the 26th edition of the symposium, along with a tutorial and several affiliated workshops, was held at the Fields Institute. The main symposium ran from Tuesday, June 21 to Friday, June 24 and the workshops and tutorial were held on Monday, June 20 and Saturday, June 25. Next year's LICS Symposium will be held in Dubrovnik, Croatia, from June 25 to 28, 2012.

At this year's meeting, the 85 participants attended the invited lectures by Naoki Kobayashi (Tohoku University), Andrei Krokhin (University of Durham), Toniann Pitassi (University of Toronto), and Ashish Tiwari (SRI). In addition to the invited talks, 37 contributed papers were selected for presentation from 114 submitted papers. The program committee for the meeting was chaired by Martin Grohe of the Humboldt Universität zu Berlin. Tutorials by Albert Atserias (UPC Barcelona) and Prakash Panangaden (McGill) on Finite Model Theory and Semantics were presented on the 20th.

Three workshops were held at Fields in conjunction with the LICS symposium: the workshop on Syntax and Semantics of Low-Level Languages, the workshop on Logical Aspects of Fault-Tolerance, and the workshop on Logic and Computational Complexity.

During the meeting, Willem Heijltjes was awarded the Kleene prize for best student paper presented at the Symposium and the LICS Test-of-Time Award was presented to Patrice Godefroid and Pierre Wolper, Joshua Hodas and Dale Miller, and Dexter Kozen for papers that they presented 20 years ago at the 1991 LICS Symposium.

The organizers of the LICS Symposium would like to express their gratitude to the staff of the Fields Institute for their support of this meeting. In addition, we acknowledge the financial assistance of Microsoft Research, Redmond, Washington.

Conference in Number Theory

June 27-29, 2011, Held at Carleton University

Organizers: Saban Alaca, Abdellah Sebbar, Hugh C. Williams, Kenneth S. Williams.

This conference was supported by the Fields Institute, MITACS and Carleton University. The goal of the conference was to bring together top researchers in number theory and related fields from Canada and abroad in order to foster collaboration and to expose students to important problems in the field. There were 12 invited speakers and 10 contributed talks. The total number of participants was 50. Approximately half of the participants were graduate students.

The first day's lectures were given by Gary Walsh (University of Ottawa), Edlyn Teske-Wilson (University of Waterloo), Matilde Lalin (Université de Montréal) and Matthew Greenberg (University of Calgary). Gary Walsh described some recent developments on the computation and existence of rational and integral points on elliptic curves. Edlyn Teske-Wilson discussed the problem of homomorphic encryption. Matilde Lalin described her generalization of the classical Mahler measure of a nonzero polynomial in several variables. Matthew Greenberg discussed the evolution of computational methods for automorphic forms.

The second day's lectures were given by Stephen Choi (Simon Fraser), Todd Cochrane (Kansas), Hugh Montgomery (Michigan) and Kumar Murty (University of Toronto). Stephen Choi discussed his recent work on the norms over the unit circle of Littlewood polynomials, that is, polynomials with coefficients $+1$ or -1 . Todd Cochrane described various estimates for Waring's number (the least positive integer s such that every integer is a sum of s k -th powers modulo a prime p). Hugh Montgomery spoke about a one-parameter family of polynomials (of which the eulerian polynomials are a special case) which arose out of the work of Mauduit and Rivat which settled a problem posed by Gelfand in 1968. Kumar Murty talked about the lifting of elliptic curves over the field of p elements to characteristic zero.

The third and final day's speakers were Lawrence Washington (Maryland), Renate Scheidler (University of Calgary), Karl Dilcher (Dalhousie) and Damien Roy (University of Ottawa). Lawrence Washington described recent work on the determination of the class numbers of real cyclotomic fields. Renate Scheidler described the arithmetic framework of the baby step giant step algorithm in a general setting. Karl Dilcher described his joint work with J. B. Cosgrave on the determination of a certain central binomial coefficient modulo p^3 extending the work of Chowla, Dwork and Evans on the

mod p^2 case. Damien Roy gave the final talk of the conference. He discussed some joint work with S. Lozier on the rational approximation to real points on algebraic curves with special reference to the case of the curve defined by the polynomial $x^2z - y^3$.

Abdellah Sebbar ran a problem session. The proposed problems will be listed on the conference's website.

The conference ran very smoothly and at the end of the conference Hugh Montgomery thanked the organizers on behalf of the participants for a very successful conference. On a personal note he indicated that he particularly liked the broad spectrum of talks across number theory and cryptography.

Séminaire de Mathématiques Supérieures (SMS) 2011
Metric measure spaces: geometric and analytic aspects
June 27 - July 8, 2011, Held at CRM

Organizers: G. Dafni (Concordia University), R. McCann (University of Toronto), A. Stancu (Concordia University)

In recent decades, metric-measure spaces have emerged as a fruitful source of mathematical questions in their own right, and as indispensable tools for addressing classical problems in geometry, topology, dynamical systems, and partial differential equations.

Our 2011 summer school was designed to lead young scientists to the research frontier concerning the analysis and geometry of metric-measure spaces, by exposing them to a series of minicourses featuring leading researchers who highlighted both the state-of-the-art and some of the exciting challenges that remain.

The mini-courses could be grouped into three broad categories: (i) analytical aspects of metric spaces, (ii) functional and metric geometry, and (iii) techniques from optimal transportation — which has emerged as an important collection of ideas build useful links between (i) and (ii). They were all of an exceptionally high quality. It was clear that the speakers had spent a lot of time and effort preparing the material and this was very much appreciated by the audience. Moreover, many of the speakers attended the other mini-courses and this generated interesting interactions. A couple of senior participants — Nicola Gigli (Universite de Nice), a co-author of several of the speakers, and Frank Morgan (Williams College) — were present, for all or part of the school, and actively involved in the discussions. After each lecture there was time for questions from the students, which ranged from elementary to very knowledgeable. Often students and lecturers continued the discussions between the talks and during the lunch breaks.

The mini-courses came under the themes outlined above, with certain talks providing links between them. The third and most prevalent was the use of ideas from optimal transportation to define geometric notions on metric measure spaces, in particular the notion of lower curvature bounds. Yann Ollivier began the school by introducing a

definition of discrete Ricci curvature on metric spaces, based on the idea of comparing the (average transportation) distance between balls to the distance between their centers. Ollivier's talks were complemented on the one hand by Vitali Kapovitch's lectures, emphasizing the Riemannian geometry point of view, and on the other by Robert McCann's lectures on optimal transportation. Kapovitch described the consequences of curvature bounds on Riemannian manifolds, comparing in particular Ricci curvature versus sectional curvature, and metric analogs in Aleksandrov spaces. McCann's mini-course provided students with insight into the techniques and applications of optimal transportation starting with the classical transportation problem of Monge and Kantorovich and leading to the recent theorems concerning smoothness of optimal maps by Ma, Trudinger, Wang and Loeper. Along the way there were excursions into two-player zero sum games, convex duality and linear programming, fully nonlinear partial differential equations, the economics of optimal pricing, and connections with minimal Lagrangian submanifolds in semi-Riemannian geometry.

This theme was taken up in the second week by Karl-Theodor Sturm, who spoke about the celebrated curvature-dimension condition for metric measure spaces, originating in his work and that of Lott-Villani (with ideas tracing back to the work of McCann). He introduced a variant of this condition, the so-called "reduced curvature-dimension condition", which has the local-to-global property. The mini-course concluded with a detailed exposition of the relevant notions and results in the setting of Finsler spaces. The discussion of optimal transportation started by McCann continued with a series of talks by Young-Heon Kim on Ma-Trudinger-Wang curvature and regularity of optimal transport. In this theory, the non-negativity of certain sectional curvatures of a metric induced by the transportation cost turns out to be necessary and sufficient for the smoothness of optimal maps. Focusing his talks in the Riemannian setting, Kim outlined the state-of-the-art through a series of examples and counterexamples, building up to his recent joint work on Holder continuity of optimal maps between not-necessarily-smooth distributions of mass. The course by Felix Otto illustrated further uses of notions coming from optimal transportation, in particular the Wasserstein distance, in partial differential equations from applied mathematics modeling dissipative mixing of immiscible fluids. Here he revisited his classical bound on the nonlinear mixing rate. This appears uncontrolled in the linearized regime due to the Rayleigh-Taylor instability, which predicts that thin fingers of fluid grow faster, with the thinnest fingers growing arbitrarily fast. More than a decade ago, Otto coarse-grained the dynamics, to show that the average fluid density as a function of its height obeys a Burger's type equation which predicts mixing at a bounded rate. In a recent preprint with Gigli, he showed that this dynamics actually represents a gradient flow in a metric space setting, which picks out the unique entropy solution to the scalar conservation law, as explained in his lectures.

The second theme of the summer school, roughly coming under the "analytic aspects" of metric spaces, concerned notions of differentiability on metric measure spaces and the corresponding function spaces. This theme started in the first week with the parallel series of lectures by Piotr Hajlasz and Pekka Koskela. Without relying on much background from the audience, Hajlasz succeeded in introducing students to the fascinating and sometimes surprising world of Sobolev mappings between manifolds,

from manifolds into metric spaces and between metric spaces, in which basic facts such as approximation by smooth or Lipschitz functions cannot be taken for granted, and may depend on topological properties involving homotopy groups (in the case of manifolds). Koskela's dynamic lectures exposed the audience to questions from the theory of quasi-conformal mappings in the context of (Ahlfors regular) metric-measure spaces, covering in detail the regularity of QC maps, the notion of quasi-symmetry, and the function spaces preserved under these maps. In addition to Sobolev spaces (using the definition given by Hajlasz), recent work by Koskela, Yang and Zhou was described, showing that certain appropriately defined Besov and Triebel-Lizorkin spaces are preserved.

The two themes described above came together in the mini-course by Luigi Ambrosio in the school's second week. Ambrosio reviewed and compared various notions of weak gradients and Sobolev spaces in metric measure spaces, such as upper gradients (due to Heinonen and Koskela), absolute continuity on lines (a definition by Levi extended to metric measure spaces by Shanmugalingam), and Cheeger's energy, and showed the identification of weak gradients using optimal transportation techniques, without relying on doubling or Poincare assumptions. These exciting results (joint work of Ambrosio with Gigli and Savare) used a gradient flow based on the Wasserstein distance and the curvature-dimension conditions of Lott-Sturm-Villani.

The final theme could be described as functional and geometric inequalities. The mini-course of Ollivier concluded with results on concentration of measure and the Brunn-Minkowski inequality for the discrete hypercube (the latter joint work with Villani), part of the body of work for which he was awarded the 2011 CNRS bronze medal. The course of Emanuel Milman, spanning the two weeks, described the relations between isoperimetric inequalities, concentration of measure, and functional inequalities such as Poincare, Sobolev and log-Sobolev. While isoperimetric inequalities imply Sobolev type inequalities, and it is known from work of Gromov-V. Milman that, in any metric space, the Poincare inequality implies exponential concentration, the reverse implications do not, generally, hold. It was thus an impressive result that in the case of a Riemannian manifold with density having lower bounds on the Bakry-Emery tensor, E. Milman showed that concentration inequalities imply isoperimetric inequalities. A main ingredient of his proof is a result of Frank Morgan, well known in geometric measure theory. The latter topic was featured in the lectures by Guy David.

Starting with the famous Plateau problem in higher dimensions (not yet solved) as an illustration, David's course discussed the structure of minimizers to functionals on currents with a given lower dimensional rectifiable current as boundary. The focus was now on the lack of smoothness, and minimizers in the sense of Almgren, concluding with the proof of Jean Taylor's theorem, which characterizes them. His nice manner of exposition was punctuated by exercises in which David engaged the audience. The relations between various inequalities were also the subject of the course by Thierry Coulhon in the second week. Again working in the Riemannian context, but this time on a non-compact manifold with volume doubling, Coulhon discussed the implications of various heat kernel estimates to L_p boundedness of Riesz transforms, an important question which relates back to the second theme since it concerns the compatibility of various definitions of weak derivatives (i.e. the weak gradient and the square-root of the

Laplacian) and the corresponding Sobolev spaces. An example was given of a fractal-like manifold where local and global bounds differ. Heat kernel estimates, and in particular this type of different local and global behaviour, also played a prominent role in the lectures by Martin Barlow, where Gaussian bounds were shown to be equivalent to a parabolic Harnack inequality on the one hand, and doubling and Poincare on the other. These inequalities (or their failure) were discussed in detail for the Sierpinski carpet. The high quality of the lectures by Barlow, Ambrosio and Kim during the last days of the school guaranteed a full audience up to the last minute.

We received 135 applications from which we selected to fund 40 participants other than speakers. Approximately 20 more participants attended without our support, mostly local graduate students, a few local faculty and a few funded by their home institutions and/or research supervisors.

About 82% of the funding for participants went to graduate students, of which we tried to select those who were already advanced in their studies and working in areas closely related to the topic of the school, and the remaining funding was directed to young PhD's (no earlier than 2008).

There were a few exceptions such as the graduate students selected by MSRI based on other criteria, and a very advanced undergraduate student from UBC who was about to enter graduate school. In the selection process, we gave priority to the applicants for whom the school could make a significant impact.

In this regard, a letter from the advisor explaining the relevance of the school for the student's program of studies was often a decisive factor. About 20% from the total number of participants, with or without funding, were female.

With the exception of the two CMS scholarships, and the 8 graduate students funded through MSRI's contribution (covering both local and travel expenses), the majority received a somewhat basic local support: 2 weeks in the student residences of the Universite de Montreal and a small supplement for daily expenses. To make up for such a small per diem, we provided a breakfast every day of the school, as well as coffee breaks. The CRM's administrative assistant was essential in the planning and the organization of the latter. For a small number of participants who requested it, we added a flat CDN\$250 aid for travel. In today's travel costs, this is a very small amount. On this basis alone, several other potential participants that we invited to the school declined to attend.

In what regards the CMS scholarships, they were awarded to two exceptionally qualified students enrolled in Canadian PhD programs. Both recipients actively engaged in the Q&A and discussions following the lectures. The MSRI funded students, supported at a higher rate than the average participant, were a bit more difficult to select due to the institute's internal policy that had to be met, and two of the confirmed participants cancelled at the last minute. It is expected that experience will help simplify this selection process in the future.

If additional funding had been available, we would have probably increased by about 10 the number of participants with financial support, but mostly we would have used the funds to provide more support toward living expenses and travel.

SEMINAR SERIES

Actuarial Science and Financial Mathematics Group Meetings

Organizer: Sebastian Jaimungal (University of Toronto)

Actuarial Science and Mathematical Finance (ASMF) are two fields that have immense impact in our global economy. Understanding how to measure, manage, and value the risks embedded in complex financial and insurance products is of paramount importance. The mathematical sciences play a major role in this enterprise and the synergy brought together from mathematics, statistics, computer science, engineering, finance and economics helps to push the field forward.

The Actuarial Science and Mathematical Finance (ASMF) Seminar Series has been running since September 2005. It began as a forum for PhD students, post doctoral fellows and faculty members to discuss current topics in ASMF, partially completed research, as well as reviews of classical works and methods. It has now evolved into a more formal seminar series with researchers from around the globe presenting their latest works; however, it retains its informal atmosphere to promote discussions, to open debate, and to allow the audience to interact. Several industry professionals regularly participate in the event and bring a very valuable grounded real world perspective to the discussions. This past year showcased talks ranging from energy markets to optimal hedging to financial econometrics.

Algebraic Combinatorics Seminar

Organizers: Nantel Bergeron, Mike Zabrocki, Chris Berg

This seminar is mostly a working seminar. Every year we choose a few problems to work on and present background material, conjectures and lines of attack trying to solve the problem as a group (including postdocs and graduate students). We also have from time to time outside speakers that are related to our current problems. We aim to have publications resulting from this work.

This year was another very successful one. The general topic of the talks was “Jeu de Taquin, Cores and k -Schur functions.” We mainly focused on finding a combinatorial interpretation of the structure coefficients of the k -Schur functions. Our work gave us a better understanding of k -Schur function indexed by a rectangle. Again, the use of the computer system SAGE was extensive in our exploration. This resulted in a submitted publication: “Expansion of k -Schur functions for maximal k -rectangles within the affine nilCoxeter algebra” by Chris Berg, Nantel Bergeron, Hugh Thomas and Mike Zabrocki.

Toward the end of the year, we invited Steve Pon from University of Connecticut to give a talk on his generalization of the definition of k -schur functions for other types. This naturally led us to a new collaboration, (Chris Berg, Nantel Bergeron, Steve Pon and Mike Zabrocki) where we explain our formulas above for other types.

Colloquium/Seminar in Applied Mathematics

Fields Analysis Working Group

Geometry and Model Theory

The idea of the seminar is to bring together people from the group in geometry and singularities at the University of Toronto (including Ed Bierstone, Askold Khovanskii, Grisha Mihalkin and Pierre Milman) and the model theory group at McMaster University (Bradd Hart, Deirdre Haskell, Patrick Speissegger and Matt Valeriote).

As we discovered in the thematic programs on algebraic model theory and on singularity and geometry at the Fields Institute in 1996-97, geometers and model theorists have many common interests. The goal of this seminar is to further explore interactions between the areas. It served as the main seminar for the program on o-minimal structures and real analytic geometry in 2009, which focussed on such interactions arising around Hilbert's 16th problem.

Infectious Disease Epidemiology Afficionados (IDEA)

Organizers: Dr. Amy Hurford (Fields Institute), Dr. David Fisman (Dalla Lana School of Public Health, University of Toronto)

The IDEA (Infectious Disease Epidemiology Afficionados) Seminar Series is a trans-disciplinary educational event, held at Fields once a month, which brings together mathematicians, epidemiologists, and public health experts to discuss topics related to infectious disease dynamics and control, and mathematical modeling of infectious diseases. This year's seminars included talks on mathematical immunology, dynamics of cholera in Haiti, and bacterial-viral coinfection and co-seasonality.

Physics/Fields Colloquium

Operator Algebra Seminar

Set Theory Seminar

Organizers:

The Set Theory Seminar at the Fields Institute ranks among the top research groups in Set Theory in the world. Each session is 80 minutes, and usually consists of recent original

research due to the speaker. The attendance varies from 15 to 25 people, and consists of a mix of faculty, postdocs, visitors, and graduate students from Fields, York, and the University of Toronto.

The topic of the seminars is not limited except that it is normally in Set Theory and its applications, with occasional excursions into other areas of Mathematical Logic, General Topology, and Combinatorics. The talks frequently focus on the specific interests of our very active local Set Theory group. These include, in addition to many aspects of pure set theory, set-theoretic topology and applications of set theory to functional analysis. The speakers are selected from among local faculty and graduate students, as well as the international research community. Recent specific topics have included descriptive set theory, selection principles, Ramsey theory, large cardinals applied to Banach spaces, singular cardinal combinatorics, and more.

The Seminar has been in existence for more than 40 years, meeting even during the summers; many well-known researchers have participated, as have Ph.D. students, postdoctoral fellows, and sabbatical visitors.

Toronto Probability Seminar

Toronto Quantum Information Seminar

Organizers:

The Quantum Information Seminar series, a joint Fields Institute/Center for Quantum Information and Quantum Control (CQIQC) program held Fridays at 11am in the Stewart Library, have had another successful and stimulating year. Our speakers, representing 11 countries, covered a wide range of both theoretical and experimental topics in quantum information and quantum control. A highlight was the public lecture by Charles Bennett from IBM who spoke in August. Dr. Bennett is a pioneer in the field of quantum information. That talk was given to a standing-room-only audience in a large campus lecture hall. The normal seminars were typically attended by 20–30 students and faculty members from diverse departments at the University of Toronto, including physics, mathematics, chemistry, electrical and computer engineering and computer science. The series highlights interdisciplinary research in the new quantum sciences that have begun to immerse in the past decade and serves as a forum for discussion and inspiration. We hosted a variety of exceptional speakers from around the world, including Andrew White (University of Queensland), David Tanner (Weizmann Institute of Science), Alan Migdall (NIST), Robert Hadfield (Heriot-Watt University, Edinburgh), and Claude Fabre (University Pierre et Marie Curie, Paris), just to give a few examples.

CENTRE FOR MATHEMATICAL MEDICINE

The 2010-2011 year was a busy one for the Centre for Mathematical Medicine. We had an active seminar series this year, where we had an excellent set of speakers and

interested audiences. The general theme of the seminars emphasized the relationships between processes in Biology and Medicine and the mathematical models that have contributed to research and understanding. Our Postdoctoral Fellows are involved in our activities, and graduate students in Mathematical Medicine have begun to graduate. Our collaborative research has produced dividends.

In the period 2010-2011 we organized and/or sponsored 7 workshops:

1. Optimization and Data Analysis in Biomedical Informatics, June 2010
2. Brain Neuromechanics Workshop, July 2010
3. Variability Round Table, Sept 2010
4. 4th Symposium on Health Technology, Oct 2010
5. RECOMB Satellite Workshop on Comparative Genomics, Oct 2010
6. Computational Neuroscientists of Upper Canada (CNUC's) Oct 20, 2010
7. Computational Neuroscientists of Upper Canada (CNUC's) December 9, 2010

In the period 2010-2011 we organized 8 seminars:

1. November 26, 2010 Professor Timothy David, University of Canterbury. The Challenge of Multiple Scales in the Biological Sciences: Applications to Cerebrovascular Perfusion
2. December 14, 2010 Professor Bard Ermentrout, University of Pittsburgh. Double or Nothing: The Blinking Brain
3. January 18, 2011 Dr. Will Ryu, University of Toronto
Bacteria and worm behavior: a systems-level study of signaling, time scales, and stereotyped motions
4. February 18, 2011 Dr. Christoph Haselwandter, Applied Physics & Materials Science, Caltech: Symmetry of membrane polyhedra.
5. March 15, 2011 Professor John Milton, Claremont Colleges. Multistability and the onset of epileptic seizures
6. April 1, 2011 Somdatta Sinha, Centre for Cellular & Molecular Biology, Hyderabad Spatiotemporal description and modeling of Malaria in India
7. April 19, 2011 Professor Michael Mackey, McGill University Using mathematical modeling to tailor the administration of G-CSF in disease states
8. June 14, 2011 Dr. Shu Takagi, University of Tokyo. On the Development of Human Body Simulator for the Next-Generation Supercomputer in Japan

1. Optimization and Data Analysis in Biomedical Informatics, June 2010

Organizing Committee: Thomas F. Coleman University of Waterloo, Sivabal Sivaloganathan, University of Waterloo, Panos Pardalos University of Florida, Petros Xanthopoulos University of Florida

This workshop explored recent progress in optimization and data analysis in biomedical informatics. Challenges and roadblocks in biomedical informatics were discussed with reference to the application of data mining, new computing technologies and paradigms (e.g., cloud computing), optimization and control, and systems engineering. Participants included both academic and industry researchers as well as practitioners in medicine and health care.

2. 26-28 July, 2010 CMM Brain Neuromechanics Workshop

Organizing Committee: C. Drapaca (Penn State), JM Drake (Hospital for Sick Children, Toronto), M. Johnston (Sunnybrook & Womens Hospital, Toronto), S. Sivaloganathan (University of Waterloo)

OVERVIEW

The brain is the most complex organ of our central nervous system. It is responsible for controlling all the other organs in the body, as well as breathing, heart beat and temperature regulation. It is also the processor of all conscious and unconscious stimuli, thought and feelings, learning and memory. As a material, the brain is an inhomogeneous, multi-scaled and multi-layered, inter-connected network of neurons, glial cells, blood vessels and extracellular matrix. The function of each of these components is interconnected and modulated by the activity of the others. The mechanical parameters of the brain are determined from both the constituent elements and their electro-chemical and mechanical interactions at all length scales.

In recent years, progress has been made in both brain biomechanics and neuroscience. However, the two research areas have developed independently of each other with little cross-fertilization, neglecting possible linkages between the electric brain and the mechanical brain. The lack of fundamental knowledge about the interactions between the electrical and mechanical properties of the brain severely inhibits the ability to interpret neural activity data. It impairs the ability to intelligently simulate the brain responses to electric and mechanic stimuli. This gap impedes the development of a wide range of feasible medical therapies.

The objective of this workshop was to lay the foundations of novel theoretical and computational models of the brain that will incorporate in a common framework, knowledge about the biomechanics and the electro-chemical processes of the brain at different length scales. These models have a wide spectrum of possible applications ranging from a more fundamental understanding mechanical deformation and stress, to damage in a range of applications from traumatic brain injury to hydrocephalus to

electrode insertion. Ultimately these models will help generate improved medical diagnoses, treatment strategies and clinical protocols. Such fundamental research may play an important role in the design of improved experimental procedures and measurements.

3. Complexity and Variability Round Table Univ. of Ottawa at Montebello, Quebec

July 26-28, 2010

Organizing Committee:

- Chair: Dr. Andrew JE Seely, MD, PhD
- Zeb Khan,

Organizing Institutions:

- Division of Thoracic Surgery, The Ottawa Hospital
- Department of Critical Care Medicine, The Ottawa Hospital
- Dynamical Analysis Lab, The Ottawa Hospital Research Institute (OHRI) Univ of Ottawa

30+ participants

OVERVIEW

The Variability Round Table is a unique initiative that brings together experts and students with knowledge of medicine, theoretical physics, and mathematics to complete the following primary objectives

- 1) to discuss theories regarding the origins and etiology of complexity in physiological signals
- 2) examine and refine the methodology of continuous variability analysis
- 3) review and discuss the clinical applications of complex systems science, and
- 4) discuss and foster trans-disciplinary collaborative research projects.

The organizing committee recognizes the importance of maintaining its academic objectives. The group has a mission to promote post-graduate education by making presentations and discussions available to graduate students according to subject themes and, subsequently collate, review and publish the resultant contributions in journals.

4. 4th Symposium on Health Technology, Oct 8, 2010 at University of Waterloo.

The symposium was focused on the integration of Engineering Sciences, and Nanotechnology in addressing fundamental problems in Biology and Medicine

ORGANIZING COMMITTEE

- Dr. John Yeow, Professor, System Design Engineering, University of Waterloo
- Negar Rasti, Chair, Mechanical and Mechatronics Engineering, University of Waterloo
- Shahed Shahir, Electrical Engineering, University of Waterloo
- Mihaela Vlasea, Mechanical and Mechatronics Engineering, University of Waterloo
- Amir Fazeli, Mechanical and Mechatronics Engineering, University of Waterloo
- Parisa Sadatmousavi, Chemical Engineering, University of Waterloo
- Madjid Soltani, University of Waterloo
- Yaser Shanjani, Mechanical and Mechatronics Engineering, University of Waterloo

OVERVIEW

The Fourth Symposium on Health Technology was an opportunity for all Ontario graduate and undergraduate students to explore biomedical engineering studies and to become aware of exciting new biomedical research performed at Waterloo and other universities. This offered a great potential for networking among graduate and undergraduate students, professors and researchers invited from various backgrounds in Bioengineering fields. The symposium was focused on the integration of Engineering Sciences, and Nanotechnology in addressing fundamental problems in Biology and Medicine. The main topics were:

- Tissue Engineering
- Stem Cells
- Drug Delivery
- Biomaterials
- Bio-informatics
- Medical Imaging
- Biomedical Devices
- MEMS

- Nano-Technology

Keynote speaker: Prof. Mohamad Sawan, Polytechnique Montréal, Montreal, Quebec.
"Brain-Machine Interfaces for Accurate Monitoring and Subsequent Treatment of Central Neural System Functions"

5. RECOMB Satellite Workshop on Comparative Genomics

University of Ottawa Oct 20, 2010

- Conference Chair: David Sankoff, University of Ottawa

OVERVIEW

This was a computational biology meeting focused on genome level evolution, models and algorithms for chromosomal rearrangement, whole genome duplication, gene families, etc. It included comparisons at the genome sequence, expression or network levels, normal or pathological, and related topics, some entirely mathematical and a few primarily biological. This work was selected from among rigorously refereed full-paper submissions and published in a Springer Lecture Notes in Computer Science proceedings volume in time to be circulated at the conference. The highlights of the conference, however, were the invited keynote speakers on recent biological/medical research in areas pertinent to the field: including Nicolas Corradi (UBC), Jan Dvorak (UC Davis), Brenda J. Andrews (Toronto), Aoife McLysaght (Dublin), Nicholas Putnam (Rice), and Andrew Clark (Cornell).

The scope of the field is broadening under the challenge of increasing numbers of large genomes being sequenced at the current time.

6. Computational Neuroscientists of Upper Canada (CNUC's) October 20, 2010

Workshop Theme: Normal and Diseased Neurological States: Experimental and Mathematical Modeling in Hippocampus

Organizers:

- Katie Ferguson, Toronto Western Research Institute and University of Toronto
- Frances Skinner, Toronto Western Research Institute and University of Toronto

7. Computational Neuroscientists of Upper Canada (CNUC's) December 9, 2010

Workshop Theme: Noise, Criticality and Dynamics: Networks and Representations

Organizers:

- Katie Ferguson, Toronto Western Research Institute and University of Toronto

- Frances Skinner, Toronto Western Research Institute and University of Toronto
1. November 26, 2010 Professor Timothy David, University of Canterbury.
The Challenge of Multiple Scales in the Biological Sciences: Applications to Cerebro-vascular Perfusion

In line with architectural advances in supercomputing science and engineering have each been posing more and more complex problems, which are defined on complex geometric physical spaces. These physical spaces are themselves defined over vast ranges of scale lengths. In order to solve problems whose scale lengths vary substantially there are two possible solutions. Either discretise down to the smallest scale with the possibility of producing such large data sets and numbers of equations that the memory requirements become too large for the machine or divide the problem into a subset of appropriate length scales and map these discretised sub-domains onto appropriate machine architectures. The definition of "appropriate" here is determined on a case-by-case basis at present.

There are a significant number of problems that exhibit a large range of physical scales but none so prominent in the 21st Century as that exemplified within the biological sciences. In the major arterial networks the blood flow dynamic scales are of the order of 1mm (cerebral vessels) up to 25mm (ascending aorta). Downstream of any major vessel exists a substantial network of arteries, arterioles and capillaries whose characteristic length scales reach the order of 10-20 microns. Within the walls of these cylindrical vessels lie ion channels consisting of proteins (100 nanometers and smaller) folded in such a way as to allow only certain molecules through the membrane. One can now of course ask the question as to why all these scales should be integrated into a single model.

To investigate the way in which the brain responds to variations in pressure and yet maintains a virtually constant supply of blood to the tissue numerical models need to be able to have a representation of not only the vascular tree but also a dynamic model of how the small arteries constrict and dilate. Simulating this phenomenon as a "lumped" connection of arteries is insufficient since different parts of the arterial tree respond differently. Thus we have a range of scales from the major arteries down to the arteriolar bed. The combination of a 3D model taken from MR data coupled with an autoregulation model with a fully populated arterial tree able to regulate dynamically remains a relatively unexplored field. This particular talk will outline the reasons for investigating multiple scales and their particular constraints with special reference to the autoregulation of blood in the cerebro-vasculature and outline a possible solution.

Our Report on the David talk:

Tim David is the director of the Centre of Bioengineering and a Director of Blue Fern a supercomputing unit, comprising both SMP and a Blue Gene. Tim spoke about how he uses Blue Fern to model blood flow within the human brain, a complex problem defined on a complex geometric physical space. There are pressures placed on the arterial system of the human brain when one stands up from a sitting or lying position. Nevertheless, the flow of blood and oxygen is kept quite constant by subtle and marvelous features of the arterial geometry. In an adult, 15% of the cardiac output is fed to the brain, but it is

regulated to meet the brain's demands. Too much or too little brain blood pressure or flow creates serious health problems. Professor David models the brain's response to pressure variation to maintain a virtually constant supply of blood to the tissue.

His numerical models describe both the vascular tree and a dynamic model of how small arteries constrict and dilate. Simulating this phenomenon as a "lumped" connection of arteries is inadequate since different parts of the arterial tree respond differently. The perfusion of blood to the brain, from the outside in, is modeled using the full complexity of fluid dynamics, including considerations of viscous and turbulent flow, Reynolds numbers, et al. He deals with the pressures and flows at the boundaries of the blood vessels. The brain blood network has a range of length scales, ranging in size from 1-25 millimetres in major arteries down to 10-20 microns in the blood vessel network of network of arteries, arterioles and capillaries. Arteries perfuse the cerebral cortex from the "outside in" where "penetrating" arteries spread perpendicularly in to the cortex.

One of his major contributions is the realization of the need to distinguish these scales, and integrate them into a single cohesive model. The arteries are built in layers like coaxial cables, but they have the capacity to stretch when pressure changes quickly. Consciousness depends on this capability. Models of Calcium levels in the smooth muscle cells that surround the arteries provide mechanisms that change arterial diameters. Biochemical pathways from glutamate and potassium perfusion seem to explain dilation.

He models how the brain manages autoregulation by using conservation of CO_2 . There is a vascular tree process of blood vessels that have up to 4 million segments and 2 million leaves in current models. Each leaf connects to a capillary bed. There are 6 major connected trees that form a network of arteries, arterioles and capillaries. All of this information, plus biochemical reactions are integrated into a single model. Professor David has learned how to create asymmetric 3-D binary trees whose bifurcation is controlled by conservation of energy. He determines the ratio of daughter to parent using simple models. His models are tested against MRIs of human brains, which can measure the flows in major blood vessels. He notes that the pathology of the Alzheimer brain shows amyloid clumps that could possibly be the result (instead of the cause) of poor perfusion.

Tim David might be described as a Renaissance man or polymath; a scholar whose expertise spans a significant number of different complex subject areas. He is attempting to model a nearly intractable object--the human brain--using deep knowledge of Medicine, Anatomy, Biology, Biochemistry, Mathematics and Computer Science. We wish him success.

2. December 14, 2010 Professor Bard Ermentrout, University of Pittsburgh
Double or Nothing: The Blinking Brain.

In this talk two kinds of visual phenomena that are produced by periodically forcing the visual system were discussed. In both cases, spatiotemporal patterns are generated by nonlinear interactions of the stimulus with the underlying dynamics of the visual system. Period doubling bifurcations lead to slowly modulated bistability in one case and spontaneous symmetry breaking in the other. Normal form analysis allows one to also

explain why some patterns are seen at low frequencies while others are seen at high strobe frequencies.

3. January 18, 2011 Dr. Will Ryu, University of Toronto
Bacteria and worm behavior: a systems-level study of signaling, time scales, and stereotyped motions.

E. coli, a flagellated bacterium, has a natural behavioral variable---the direction of rotation of its flagellar rotary motor. Monitoring this one-dimensional motor response in reaction to chemical perturbation has been instrumental in understanding how *E. coli* performs chemotaxis at the genetic, physiological, and computational level. We are applying this experimental strategy to the study of bacterial thermotaxis - a sensory mode that is less well understood. To investigate bacterial thermosensation we subject single cells to well defined thermal stimuli such as impulses of heat produced by an IR laser and discover computational properties of the sensory network from their response. Higher organisms may have more complicated behavioral outputs because their motions have more degrees of freedom. Here we provide a comprehensive analysis of motor behavior of such an organism -- the nematode *C. elegans*. Using tracking video-microscopy we capture a worm's image and extract the skeleton of the shape as a head-to-tail ordered collection of tangent angles sampled along the curve. Applying principal components analysis we show that the space of shapes is remarkably low dimensional, with four dimensions accounting for > 95% of the shape variance, and that these dimensions align with behaviorally relevant states. We also partially construct equations of motion and show that the stochastic dynamics within this shape space predicts transitions between attractors corresponding to abrupt reversals in crawling direction. With no free parameters, our inferred stochastic dynamical system generates reversals time scales and stereotyped trajectories in close agreements with experimental observations.

4. February 18, 2011 Dr. Christoph Haselwandter, Applied Physics & Materials Science, Caltech: Symmetry of membrane polyhedra.

A mechanistic understanding of biological cell membranes in terms of coarse-grained physical theories requires information about the molecular properties of membranes. It has been proposed that polyhedral bilayer vesicles-symmetrical, hollow vesicles which, as observed in recent experiments, are formed spontaneously by certain amphiphilic molecules-may offer a route towards a more detailed understanding of the structure of membrane components and the energetics of their interactions. Motivated by these experiments, the elastic bending energy of polyhedral bilayer vesicles is studied. Allowing for segregation of excess amphiphiles with large spontaneous curvature along the ridges of bilayer polyhedra, we find that polyhedral bilayer vesicles can indeed have lower bending energies than spherical bilayer vesicles. However, our analysis also implies that, contrary to what has been suggested on the basis of experiments, the snub dodecahedron and the snub cube, rather than the icosahedron, generally represent the energetically favorable shapes of bilayer polyhedra.

Biography: Dr. Haselwandter has been a member of the Physical Biology of the Cell Group led by Prof. Rob Phillips at California Institute of Technology since 2009, where

his research focuses on the connection between physical and biological properties of cell membranes

5. March 15, 2011 Professor John Milton, Claremont College
Multistability and the onset of epileptic seizures

An understanding of phenomena that occur at the edge of stability may provide important clues for both the detection of impending seizures as well as their prevention. In this talk the effects of noise and time delay on switching between attractors in a bistable dynamical system were discussed. The discussion is motivated by a consideration of the timing of epileptic seizures in patients with nocturnal frontal lobe epilepsy. In this rare, familial form of epilepsy seizures occur only during sleep and most commonly during the transition between sleep stages I and II. Qualitative arguments and computer simulations of a bistable two-neuron network with delayed mutual inhibition are used to demonstrate that neural populations are particularly vulnerable for the production of paroxysmal transient events at times when changes between attractors occur. These paroxysmal events take the form of delay-induced oscillatory transients which can last orders of magnitude longer than the neural conduction delay. These arguments emphasize the importance of careful studies of the timing of seizure occurrences with respect to sleep stage transitions in patients with nocturnal frontal lobe epilepsy.

6. April 1, 2011 Somdatta Sinha, Centre for Cellular & Molecular Biology,
Hyderabad Spatiotemporal description and modeling of Malaria in India.

Malaria is one of the major vector-borne diseases causing mortality in many parts of the world, including the Indian subcontinent. In this talk the available disease prevalence data from different parts of India was presented, and the prevalence of the disease in space and time was demonstrated to give important features of its distribution. An epidemiological compartment model was discussed that described Malaria prevalence data in different cities of India with varied environmental factors. A statistical approach to model these data sets was given.

7. April 19, 2011 Professor Michael Mackey, McGill University
Using mathematical modeling to tailor the administration of G-CSF in disease states.

In this talk recent preliminary work on using mathematical models for the regulation of human hematopoiesis to investigate optimal delivery strategies for granulocyte colony stimulating factor (G-CSF) was described. This was applied to the treatment of patients with cyclical neutropenia, and to aid patients in the post-chemotherapy phase.

8. June 14, 2011 Dr. Shu Takagi, University of Tokyo. On the Development of
Human Body Simulator for the Next-Generation Supercomputer in Japan

The next generation supercomputer of 10 Peta flops speed is now under construction as a national project in Japan. Both hardware development and also software development is anticipated. The software development for the human body simulator is assigned as a grand challenge program for the effective use of this supercomputer. In this program, the multiscale and multi-physics natures of the living matter are emphasized. Under this

concept, we are developing the multiscale simulator for a living human body. Basic strategy of the simulator is to utilize the medical image data taken by MRI, CT, or ultrasound for the prediction of disease and planning of therapy. For this purpose, we have developed full Eulerian fluid-structure-interaction solver without mesh generation procedure, which enables us to conduct the simulations directly from medical images. The method is based on the finite difference scheme with fractional step algorithm for incompressible flows and materials. In this talk, the current stage of the project is introduced. One of the software applications which utilizes the full Eulerian solver and the multiscale thrombosis simulator is explained at the current stage of development of the numerical methods. Future directions of this research and development are discussed.

COMMERCIAL/INDUSTRIAL MATHEMATICS

Quantitative Finance Seminar

September 2010 – April 2011

Held at the Fields Institute

Organizers: Ron Dembo (zerofootprint), Matheus Grasselli (McMaster), John Hull (Toronto), Tom Hurd (McMaster), Moshe Milevsky (York), and Dan Rosen (R2 Financial Technologies)

Six Wednesday evenings over the past year a broad audience of academics and finance industry practitioners met at Fields to attend the sixteenth annual series of Quantitative Finance Seminars. We heard from eleven distinguished speakers who addressed a diversity of themes. Some talks were mostly mathematical, with a taste of finance, touching on probability theory (Alexey Kuznetsov, the first passage problem for Levy processes), numerical partial differential equations (Kostas Kardaras, pricing of barrier options) and the properties of affine processes (Patrick Cheridito). Other talks introduced new models for financial securities. We heard how jump diffusions and time changes can be fit together into a flexible credit risk modeling framework for multiple firms (Raphael Mendoza-Arriga). We found out why industry practitioners rely on the volatility surface as a description of market option prices and how this point of view leads to a new dynamic approach to modeling option prices (Liuren Wu). In incomplete markets, where not all risks can be hedged, different risk-neutral pricing models may yield a range of no-arbitrage prices. In such markets an investor faces a challenging mathematical problem of determining the optimal time to buy a security, based on the observed difference between the market price of a security and the model price (Mike Ludkowski). Another modeling talk studied long-term contracts, specifically S & P 500 options and CDX index tranche spreads, and how their prices can be used to extract information about the timing of firm defaults (Pierre Collin-Dufresne). The principal-agent problem in corporate finance deals with employment contracts that protect or promote the employer's interests by motivating the employee to perform, and we learned about conditions where use of stock options as compensation can be a most effective tool (Fernando Zapatero). A very important topic we heard about this session but not frequently touched on in other years

is systemic risk: the risk that a shock to one or more financial institutions triggering a worsening of the credit quality of other financial institutions, leading to the potential for chains of bank collapses and a freezing of market liquidity (Alfred Lehar). We also learned about behavioural finance and how portfolio choice within the cumulative prospect theory leads to natural but novel types of optimization problems (Xunyu Zhou). Finally, one speaker (Emanuel Derman) delved into a philosophical vein aiming to better understand the use and misuse of models in finance. He pointed out that good models in finance are not theories but rather idealizations that always sweep dirt under the carpet, but are honest about the kind of dirt.

Industrial Optimization Seminar

Held at the Fields Institute

Organizing and Advisory Committees: Antoine Deza (McMaster), Bartosz Protas (McMaster), Danielle Zyngier (McMaster), Tamás Terlaky (Lehigh), Natalia Alexandrov (NASA), Miguel Anjos (École Polytechnique de Montréal), Benoit Chachuat (Imperial College London), Andrew R. Conn (IBM Watson), Fassi Kafyeke (Bombardier Aerospace), Stefan Karisch (Carmen Systems), Joaquim Martins (Michigan), Hans Tuenter (Ontario Power Generation), Henry Wolkowicz (Waterloo), Margaret H. Wright (NYU)

The inaugural meeting of the Fields Industrial Optimization Seminar took place on November 2, 2004. This year was the seventh year for the seminar series, which is supported by both MITACS and the Fields Institute. The seminar meets in the early evening of the first Tuesday of each month. Each meeting is comprised of two related lectures on a topic in optimization; typically, one speaker is a university-based researcher and the other is from the private or government sector. The series welcomes the participation of everyone in the academic or industrial community with an interest in optimization – theory or practice, expert or student.

This year the seminar series continued its established tradition and brought together a wide range of researchers and practitioners from Canada, USA and Europe. The October seminar paired a researcher from Clemson University with the vice-president of FICO (Fair Isaac Corporation) who talked about the latest developments on optimization solvers -- Couenne and XPress suite, respectively. November talks focused on issues related to wireless communications, with one speaker from McMaster University, and the other, the manager of the RIM-Carleton Research Project. The December talks brought together a professor from the Université Catholique de Louvain, who addressed improvements in solution methods for black-box models, and a researcher from ProSensus Inc., who talked about several industrial instances of optimization problems in the food industry. The February seminars featured speakers from the University of Ottawa and Honeywell Process Solutions, and addressed issues related to design of hydrogen fuel cells, as well as an overview of nonlinear model predictive optimal control technology in industry. In March, speakers from Carnegie Mellon University and Praxair R&D combined topics related to global optimization of nonconvex NLPs and MINLPs with risk management issues related to supply chain problems in the industrial gases

sector. The April seminar speakers consisted of a professor from Wayne State University who addressed a method for solving systems of nonlinear equations with non-smooth continuous functions, and a researcher from Suncor Energy who addressed the topic of integration between production planning and scheduling problems. The main topic of the May seminar was optimized maintenance scheduling, with speakers from the University of Toronto as well as from Hydro One. Finally, the June seminar speakers from Queen's University and from Keith Marchildon Chemical Process Design Inc. focused on the topic of how to adequately develop fundamental process models.

The Fields Industrial Optimization Seminar resumes in October 2011.

Speakers for the 2010/2011 series:

October 5, 2010

Pietro Belotti (Clemson University)

Couenne, an Open-Source solver for non-convex Mixed Integer Nonlinear Optimization

Alkis Vazacopoulos (FICO)

Using Mixed Integer Programming to Solve Sequencing, Scheduling and Packing Problems

November 2, 2010

Tim Davidson (McMaster University)

Semidefinite relaxation in action: Efficient "soft" demodulation for wireless communication systems with multiple antennas

Ramy Gohary (RIM-Carleton Research Project)

Jointly Optimal Design of The Transmit Covariance and The Relay Precoder in Amplify-and-Forward Relay Channels

December 7, 2010

Yurii Nesterov (Université Catholique de Louvain)

Recent advances in Structural Optimization

Ivan Miletic (ProSensus, Inc.)

Data-Driven Models in Industrial Applications of Optimization Methods

February 1, 2011

Arian Novruzi (University of Ottawa)

Optimal shape design and hydrogen fuel cells

Jeff Renfro (Honeywell Process Solutions)

Overview of a Nonlinear Model Predictive Optimal Control Technology used in Industrial Process Control Applications

March 1, 2011

Nick Sahinidis (Carnegie Mellon University)
Global optimization of nonconvex NLPs and MINLPs with BARON

Jose M. Pinto (Praxair R&D)
Risk Management in the Industrial Gas Supply Chain

April 5, 2011
Boris Mordukhovich (Wayne State University)
Generalized Newton's Method Based on Graphical Derivatives

San Yip (Suncor Energy)
Challenges of Integrating Planning and Scheduling in Oil Industry

May 3, 2011
Andrew Jardine and Dragan Banjevic (University of Toronto)
On the Optimization of Condition-Based Maintenance Decisions

Norm Hann (Hydro One)
Closing the Crevice: Achieving Valuable Maintenance Analyses by Linking Corporate Data with Maintenance Analysis Software

June 7, 2011
Kim B. McAuley (Queen's University)
Optimization for Development of Reliable Fundamental Models

Keith Marchildon (Keith Marchildon Chemical Process Design Inc.)
Modeling Successes in a Polymer Production Process

MATH EDUCATION

Ontario Mathematics Education Forum

Mathematics Education Forum Steering Committee

Co-chairs: Dragana Martinovic (University of Windsor) and Matthias Neufang (Fields Institute)

Members: Iain Brodie (Toronto District School Board), Stewart Craven (Ontario Science Centre), Shirley Dalrymple (York Region District School Board), Jeff Gardner (Hamilton-Wentworth District School Board), John Kezys (Mohawk College), Donna Kotsopolous (Wilfrid Laurier University), Miroslav Lovric (McMaster University), Ami Mamolo (York University), Joyce Mgombelo (Brock University), and Chris Suurtamm (University of Ottawa).

Mathematics Education (MathEd) Forum meets at the Fields Institute monthly during the school year, for a total of seven meetings (2010/11 dates were: September 25, October 30, November 27, January 29, February 26, March 26, April 30), from 10am-2pm. Attendance ranges from 20 to 45, and participants come regularly from as far as Ottawa, Kingston, Peterborough, London, Windsor, and St. Catharines. Meetings are open to the public and anyone may attend without invitation, although there is a substantial core membership that attends regularly. Agendas are discussed and defined at the meetings of the Forum's Steering Committee; there were five Steering Committee meetings in 2010/11; the first was a teleconference at the end of August 2010 where the dates of the Forum meetings were determined, as well as the agenda for the September meeting. We have also identified some issues that needed more time to discuss, such as "Raising our voice in the province; having greater presence and impact," and decided to organize one ad hoc Steering Committee meeting in September.

The outcomes of the September ad hoc Steering Committee meeting were the following: recommendations for improvement of the Forum Web site, and various promotional activities that we started, including: publishing reports in professional journals with varied audiences (e.g., teachers, mathematicians, mathematics educators); establishing the *Fields Mathematics Education Journal* (FMEJ, Editors: Kotsopoulos and Martinovic); and creating posters for the meetings.

In this year also, the Forum continued to bring together individuals from university and college mathematics departments, faculties of education, teachers and mathematics coordinators from school boards, textbook publishers, freelance consultants, government representatives as well as members of the public interested in mathematics education.

The Forum serves as a lively venue for sharing ideas and initiatives, discussing current issues in mathematics education and beyond, forging partnerships for mathematics education research, planning activities for mathematics education conferences and presenting numerous outreach activities.

No matter what activity, certain questions remain focus of our discussions, such as: How to improve teaching and learning of mathematics? How to better prepare mathematics teachers? How to stimulate interest in studying and teaching mathematics? How to improve communication between primary and secondary teachers, and university instructors?

In 2010/11 we witnessed a further increase in attendance and active participation among graduate students (mostly in mathematics education; there were few mathematics grad students as well). At some meetings about one-quarter of the attendees were graduate students.

Among our international guest speakers in 2010/11, we mention:

- Susan Goldin-Meadow (University of Chicago, IL)
- Brenda Gunderson (University of Michigan, MI)
- Gizem Karaali (Pomona College, Claremont, CA)
- Sandy Zabell (Northwestern University, Chicago, IL)
- Stephen Lerman (London South Bank University, UK)

Each meeting starts with information about activities of various mathematics education groups/organizations OAME (Ontario Association for Mathematics Education), OMCA (Ontario Mathematics Coordinators Association), OCMA (Ontario Colleges Mathematics Association), CMESG (Canadian Math Education Forum) and others. Then, the theme of the meeting is announced, and the Steering Committee members in charge of organizing the theme introduce the activities that follow.

Description of Meetings:

1. The meeting on *September 25* was created around the theme “*What (event, emotion, experience, ...) inspired you to dedicate yourself to mathematics education?*” This was a prelude to the November session on Humanistic Mathematics. We were joined by the Humanistic Mathematics group over the video-conference. Activities included pair-and-share, group sharing, telling stories, and the whole group discussion.

During the afternoon, Susan Goldin-Meadow (University of Chicago, IL) gave a presentation on: “*How our hands help us think about math*”. She raised the possibility that gesture might do more than just reflect learning -- it might be involved in the learning process itself, so that it directly influences the learner and indirectly influences the learning environment.

2. The meeting on October 30 was the third meeting of the Forum that was not held at the Fields Institute, in Toronto. In order to expand our reach and better engage communities outside of Toronto region, we chose to run this forum at University of Windsor. Besides the regular Forum attendees, we had a good attendance from the Windsor region.

The theme was *Equity in Mathematics Education*, and presentations included panel discussion with Pat Rogers (University of Windsor), Florence Glanfield (University of Alberta), Immaculate Namukasa (University of Western Ontario), and Richard Barwell (University of Ottawa) as panellists; and Brenda Gunderson (University of Michigan), who talked about instructional technologies that can enhance teaching and promote student learning. Having such a variety of speakers (i.e., mathematicians, teachers, educational researchers, statisticians) and topics, in addition to visiting the University of Windsor and facilities, was both educational and engaging for the Forum members.

3. The theme of our November 27 meeting was *Humanistic Mathematics*. The speakers included: Gizem Karaali (Pomona College, Claremont, CA), an Editor of the Journal of Humanistic Mathematics; George Gadanidis (UWO, London) who presented children’s drawings of mathematicians “at work”; Miroslav Lovric (McMaster U, Hamilton), Shirley Darlymple and Iain Brodie (Toronto DSB, Toronto, ON), who gave students a voice through video interviews; and Burke Brown (UT, Toronto), who talked about branding “*humanistic mathematics*”.

4. The January 29 meeting was dedicated to research. The novelty of this meeting was in 13 poster presentations organized in the lobby during the lunch break. There were also six presentations on recent research projects:

Gregory Belostotski (University of Alberta) talked about *Student Questions in Mathematics Classrooms: Teacher Interpretation and Student Repair*. The presenter explored the nature of student questions with particular attention to the role of teacher interpretation and student question repair.

Lorraine Dame & Gary MacGillivray (University of Victoria), discussed *Student Readiness and Success in Entry Level Undergraduate Mathematics*, and particularly which elements of a student's preparation are predictors of success in entry level undergraduate math (ELUM) courses.

Patricia Byers' (Georgian College) presentation on *An Investigation of Trigonometric Representations as a Source of Student Difficulties* introduced numerous issues around the treatment of trigonometry in selected secondary and college textbooks that may contribute to a lack of coherence for the learner.

Vanessa Vakharia (University of British Columbia) gave an engaging talk about *Peace, love, and pi: Imagining a world where Paris Hilton loves mathematics*.

Jenny Sealy Badee (Mathematics Education Consultant) discussed *Teachers' opportunities to learn to use multiple representations of mathematical ideas*. She addressed scarcity of use of graphs and no opportunity to link graphs and symbols in the curriculum.

The meeting was finalized with a presentation from Cathy Bruce, Tara Flynn (Trent University), and Laurie Moher (Kawartha Pine Ridge DSB) on their *collaborative action research as an effective model for professional development in mathematics*. Their team found evidence of significant teacher learning (including deeper understandings of patterning and algebra) and shifts in teacher beliefs about their math teaching (such as raised expectations for students and higher teacher confidence).

5. The February 26 Forum meeting was related to "*Cultural Differences in Ways of Doing (and Teaching) Mathematics*".

The presenters gave a cultural perspective on teaching and learning mathematics and also brought artefacts from several countries. The presenters included: Cecilia Kutas (OISE/UT), who talked about *Math education in Hungary, K-4*; Priscilla Bengo (OISE/UT) who presented on *Doing mathematics from the Chinese and Tamil perspectives*; and the panellists: Abbas Bhatti and Dagmar Musilova (York University), who described their experiences from different levels of schooling in Pakistan and Czech Republic.

The afternoon of this meeting was organized as discussion on topics presented in the morning.

6. The theme of the Forum's *March 26* meeting was "*Has Chance Been Tamed?*", and brought about the following presenters:

Sandy Zabell (Northwestern University, Chicago), who critically examined the theses advanced by Hacking in his book "The Taming of Chance."

Georges Monette (York University), who explored whether a good citizen's version of causality can be made simple enough to teach in high schools yet no so simple that it merely breeds belief in new fallacies.

Alison Gibbs (University of Toronto), who considered ideas for expanding the study of statistics in schools beyond graphical and numerical summaries of data, towards supporting sophisticated inferential reasoning in very young students.

7. The theme of the *April 30* meeting was "*The Value of Including Social Justice and Sustainability Issues in a Mathematics Curriculum*".

David Stocker (City View Alternative School in Toronto), talked about the *Pizza Party Math: A Critical Look at Elementary Mathematics Resources*.

Peter Crippin (University of Waterloo), discussed how can we, as teachers of mathematics, help affect social justice?

Jessica Young (OISE/UT), talked about *Environmental Education in Secondary Schools*, and addressed recent policy reform requiring all teachers (K-12) to teach environmental sustainability.

Stephen Lerman (London South Bank University, UK), concluded the meeting by talking about *Finding Paths to Students' Engagement and Equity in Mathematics Education*. He proposed how to improve the equity of successful outcomes in mathematics education.