CENTRE DE RECHERCHES MATHÉMATIQUES

Annual Report
1995-1996

Ce rapport est aussi disponible en français

Université de Montréal

A WORD FROM THE DIRECTOR

Recent thematic years at the CRM have alternated between fundamental domains of the mathematical sciences and applied ones. The year 1995-96 was decidedly under the applied banner. The first semester was devoted to numerical analysis and the second to applied topics in analysis (spline functions, wavelets, special functions, neural networks and finance). The scientific meetings were praised and extremely well received by the scientific community: more than 700 researchers visited the CRM for these events. We trust that the years to come (combinatorics and group theory (96-97), statistics (97-98) and number theory (98-99)) will maintain this level of popularity and scientific quality.

The industrial program at the CRM, started in 93-94, is still expanding. Four of our conferences and workshops were organized jointly with the CERCA and the CIRANO, two liaison and transfer research centres based in Montreal. The CIRANO/CRM conference on mathematical finance was supported by a number of firms and financial institutions. Four industrial postdoctoral fellowships, jointly sponsored by the CRM and non-academic partners, were given to young scientists working on applied problems. Finally, the numerical physics group PHYSNUM has joined the CRM. Because of its industrial contacts, this group has successfully helped Ph.D.'s with backgrounds in fundamental fields make the transition to industrial settings. Many PHYSNUM/CRM postdoctoral fellows have indeed found positions in industry, often before the end of their stipend.

The Canadian mathematical scene is always changing. A consortium of several universities in western Canada has created the Pacific Institute for the Mathematical Sciences (PIms) and the CRM wishes this new institute well. The CRM, the Fields Institute and the PIms are about to present a grant application to NSERC which, in addition to supporting PIms, would include funds to launch new initiatives of national scope. This national network NNCMS (*National Network for Collaboration in the Mathematical Sciences*) will offer a postdoctoral fellowship program for Ph.D.'s making the transition to industry (complementary to the one at the CRM), financial support for the organization of schools and conferences, a program for meetings on mathematical problems from industry and various programs for graduate students. The CRM would assume the chairmanship of the NNCMS management board during its first year of operation.

The recent growth of the CRM and its expanding (national) responsibilities have required the appointment, this past year, of a second deputy director. Yvan Saint-Aubin has assumed this function.

Whoever is involved in science nowadays knows how scarce funding is becoming. Therefore CRM is proud to have received, this year, a 15% increase in its three-year FCAR grant (programme Centre) for 1996-1999. The Fonds FCAR has supported the CRM since the early seventies and its role has always been crucial in maintaining the diversity of our activities. In 1994 NSERC recommended the creation of a CRM-Fields coordinating committee and established a formula for the funding of activities outside Québec. This committee first visited the CRM in October 95 and was favourably impressed by our efforts in pursuing our national mission. Indeed the budget for 94-95 (already committed when the rule was established) showed significant progress toward the goal set by NSERC. And the predictions for 95-96 indicated that the target would be met; in fact, these have been exceeded. Finally, in spite of severe budget cuts, the Université de Montréal has maintained its substantial financial support to the CRM.

The year 95-96 has been marked by several events highlighting the leadership of the CRM at the local, national and international level. We hope that this report will convey the diversity of the Centre's accomplishments. I take the opportunity to thank all those who have made them possible: the deputy directors Martin Goldstein and Yvan Saint-Aubin; the regular, associate and visiting members; the graduate students; the members of our various committees; the organizers of the scientific events; the great staff of the CRM; the administration of the Université de Montréal; all our partners and of course, André Aisenstadt.

Luc Vinet, Director

SUMMARY

PRESENTING THE CRM

The Centre de recherches mathématiques (CRM) was created in 1969 by the Université de Montréal through a special grant from the NRC. It became an NSERC national research centre in 1984. It is currently funded by NSERC (Natural Sciences and Engineering Research Council), by the Government of Québec through the Fonds FCAR pour l'aide et le soutien à la recherche and the Université de Montréal, and by private donations. The mission of the CRM is to do research in mathematics and closely related disciplines and to provide leadership in the development of the mathematical sciences in Canada.

The CRM accomplishes its mission in several ways:

- it maintains a local group of researchers chosen mainly from departments of mathematics and statistics, but also from departments of computer science, physics, economics, engineering, etc.;
- it organizes a series of scientific events each year, around a given theme (distinguished lecture series, workshops, conferences, summer schools, visitor programs, etc.);
- it works actively at developing contacts with industry through joint activities with liaison and transfer research centres (CERCA and CIRANO), research centres doing applied research (CRT, GERAD and the LACIM) and directly with industries. Activities range from the organisation of scientific conferences to an industrial postdoctoral fellowship program;
- it publishes some 150 technical reports and about 6-8 books per year. Some of its collections are published jointly with the AMS and with Springer Verlag. In addition it produces videos and software;
- each year it invites, through the Chaire Aisenstadt, one or two prestigious mathematicians to give advanced courses;
- it awards three prizes yearly: the CRM-Fields Prize recognizing major contributions to mathematics, the Aisenstadt Prize given for outstanding work done by a young Canadian mathematician, and the CAP-CRM Prize for exceptional achievement in theoretical and mathematical physics;
- it has signed protocols of collaboration with other national institutes: the Steklov Institute (Moscow) and the Nankai Institute of Mathematics (Tianjin);
- it informs the community of its activities through its Bulletin (2 or 3 issues per year) and through its rich web page **`www.CRM.UMontreal.CA`**;
- it offers first class computer services to its visitors. It is currently working on expanding the network links among the local community.

The CRM fulfils its national mission by involving the largest possible number of Canadian mathematicians in its scientific programs, both as participants and as organizers. It also supports many events taking place outside Montréal and the Province of Québec. It is recognized worldwide as one of the major institutes in the mathematical sciences. The director of the CRM is supported by two managerial structures: the Board of Directors and the Scientific Advisory Committee. The Scientific Advisory Committee is a prestigious group of internationally renowned mathematicians, both Canadian and non-Canadian, who approve scientific programs and thematic years, choose recipients of the CRM-Fields and the Aisenstadt prizes, and suggest new scientific ventures to explore. The president of the Canadian Mathematical Society is a member *ex officio*. This structure is augmented by the CRM-Fields committee that oversees the collaboration and coordination between the two institutes and assures the truly national role of both. The members are representatives of the Canadian scientific community.

PERSONNEL

THE DIRECTOR'S OFFICE

Luc VINET	*Director*
Martin GOLDSTEIN	*Deputy Director*
Yvan SAINT-AUBIN	*Deputy Director*
Diane POULIN	*Secretary*

ADMINISTRATION

Ghislain GIROUX-DUFORT	*Head of Administration*
Michèle GILBERT	*Secretary*
Isabelle SÉGUIN	*Secretary*

SCIENTIFIC ACTIVITIES

Louis PELLETIER	*Coordinator*
Josée LAFERRIÈRE	*Assistant Coordinator*
Diane BRULÉ-DE FILIPPIS	*Secretary*

PUBLICATIONS

André MONTPETIT	*TeX Expert*
Louise LETENDRE	*Technician*

COMPUTER SERVICES

Hélene HÉBERT	*UNIX Systems Manager*
David RAND	*Web & Macintosh Expert*

SCIENTIFIC PERSONNEL

Regular members

Regular members are either professors from the Université de Montréal whose teaching load has been reduced so that they can participate in research activities at the CRM, or researchers who have been appointed.

Arminjon, Paul	Dép. de math. et de stat.
Bélair, Jacques	Dép. de math. et de stat.
Broer, Abraham	Dép. de math. et de stat.
Clarke, Francis	Dép. de math. et de stat.
Delfour, Michel	Dép. de math. et de stat.
Deslauriers, Gilles	École Polytechnique
Doray, Louis	Dép. de math. et de stat.
Dubuc, Serge	Dép. de math. et de stat.
Dufresne, Daniel	Dép. de math. et de stat.
Frigon, Marlène	Dép. de math. et de stat.
Gauthier, Paul	Dép. de math. et de stat.
Goulard, Bernard	Dép. de physique
Joffe, Anatole	Dép. de math. et de stat.
Langlands, Robert	Institute for Advanced Study
Lessard, Sabin	Dép. de math. et de stat.
LeTourneux, Jean	Dép. de physique
Lina, Jean-Marc	Atlantic Nuclear Services Ltd.
Patera, Jiri	Dép. de math. et de stat.
Perron, François	Dép. de math. et de stat.
Rosenberg, Ivo	Dép. de math. et de stat.
Rousseau, Christiane	Dép. de math. et de stat.
Saint-Aubin, Yvan	Dép. de math. et de stat.
Sabidussi, Gert	Dép. de math. et de stat.
Sankoff, David	Dép. de math. et de stat.
Schlomiuk, Dana	Dép. de math. et de stat.
Van Vliet, Carolyne	Dép. de physique
Vinet, Luc	Dép. de physique
Winternitz, Pavel	Dép. de math. et de stat.
Yatracos, Yannis G.	Dép. de math. et de stat.

Associate members

Associate members are researchers who collaborate in the activities of the Centre and who have been appointed by the Board of Directors following a proposal by the director.

Ali, Twareque	Dept. of Math. and Stat., Concordia University
Fournier, Gilles	Dép. de math. et d'info., Université de Sherbrooke
Grundland, Michel	Dép. de math., Université du Québec à Trois-Rivières
Harnad, John	Dept. of Math. and Stat., Concordia University
Hurtubise, Jacques	Dept. of Math. and Stat., McGill University
Kamran, Niky	Dept. of Math. and Stat., McGill University
Sharp, Robert	Department of Physics, McGill University
Soumis, François	directeur, GERAD
Stern, Ronald	Dept. of Math. and Stat., Concordia University
Zolésio, Jean-Paul	Institut Non Linéaire de Nice

INDUSTRIAL ASSOCIATE MEMBER

Shahbazian, Élisa	Lockheed Martin Electronic Systems Canada

Visiting members

Visiting members are scientists that have been appointed in the framework of partnership agreements.

Beaulieu, Liliane	Collège de Rosemont
Bergeron, Nantel	Dept. of Math. and Stat., York University
Durand, Stéphane	Collège Édouard-Montpetit
Fournier, Richard	Collège Dawson
Gagnon, Langis	Lockheed Martin Electronic Systems Canada
Joyal, André	Dép. de math. et d'info., Université du Québec à Montréal
Leroux, Pierre	Dép. de math. et d'info., Université du Québec à Montréal
MacGibbon, Brenda	Dép. de math. et d'info., Université du Québec à Montréal
Maslowe, Sherwin	Dept. of Math. and Stat., McGill University
Mayrand, Michel	Lockheed Martin Electronic Systems Canada
Toth, John	Dept. of Math. and Stat., McGill University
Valin, Pierre	Lockheed Martin Electronic Systems Canada

Postdoctoral Fellows

The CRM receives each year several postdoctoral fellows. The source of their funding can be a national program like the NSERC postdoctoral program, the NATO international program administered by NSERC, the CRM (alone or with the ISM or the Fields Institute) or personal grants from the members. To this list, we added in 93-94 the CRM industrial program: together with our partners (CERCA and GERAD), we were able to offer four industrial fellowships this year.

Bougourzi, Hamid (NSERC)
Bykov, Nikolay (CRM-ISM)
El Gradechi, Amine (CRM-ISM)
Ferretti, Vincent
Kallel, Sadok (CRM-Fields)
Kuznetsov, Vadim B. (CRM-ISM)
Makar-Limanov, Sergei (CRM-ISM)
Lamontagne, François (NSERC)
Orlov, Aleksander (NATO)
Spiridonov, Vyacheslav
Stevenson, Katherine F. (CRM-ISM)
Van Diejen, Jan Felipe (CRM-ISM)
Watts, Gerard (NSERC International PDF)
Weston, Robert (CRM)

INDUSTRIAL POSTDOCTORAL FELLOWS

Dompierre, Julien (CRM-CERCA)
Gamache, Michel (CRM-GERAD)
Yang, Geng (CRM-CERCA)
Yu, Wei (CRM-CERCA)

MANAGEMENT

Board of Directors

The Board of Directors consists of members from the Université de Montréal (8 to 11 members) and from the outside (2 to 5 members). The recteur of the Université and the dean of the Faculté des arts et des sciences are represented on the Board of Directors. Its role is to adopt the policies of the Centre, to recommend the nomination and the promotion of researchers and the appointment of regular members, to advise the director on the preparation of the budget and the Université on the choice of the director.

Bédard, Robert	Dép. de math. et de stat., Université du Québec à Montréal
Delfour, Michel	Dép. de math. et de stat., Université de Montréal
Harnad, John	Dép. de math. et de stat., Université Concordia
Kamran, Niky	Dép. de math. et de stat., Université McGill
L'Écuyer, Pierre	Dép. d'informatique et de recherche opérationnelle., Université de Montréal
Legendre, Pierre	Dép. des sciences biologiques, Université de Montréal
Michaud, Georges	Director, CERCA
Montmarquette, Claude	Director, Dép. des sciences économiques, Université de Montréal
Tricot, Claude	Dép. de math. et génie industriel, École Polytechnique
Rousseau, Christiane	Director, Dép. de math. et de stat., Université de Montréal
St-Jacques, Maurice	vice-recteur à la recherche et à la planification, Université de Montréal
Vinet, Luc	Director, Centre de recherches mathématiques
Hubert, Joseph	vice-doyen à la recherche, Faculté des arts et des sciences

Advisory Committee

The Advisory Committee is constituted of distinguished researchers from Canada and abroad. Its members are either mathematicians or scientists with close ties to the mathematical sciences. The recteur of the Université de Montréal or his representative and the director of the CRM also take part in the meetings. The Advisory Committee is informed periodically of the activities of the Centre, through the director, and transmits any advice that it deems relevant to the Board of Directors.

Bott, Raoul	Dept. of Math., Harvard University
Dawson, Donald	Dept. of Math. and Stat., Carleton University
Fillmore, Peter A.	Dalhousie University
Kahane, Jean-Pierre	Université de Paris XI, France
Kisilevsky, Hershy	Dept. of Math., Concordia University
Lachlan, Alistair H.	Dept. of Math. and Stat., Simon Fraser University
Lalonde, François	Département de math. et d'informatique, Université du Québec à Montréal
Manin, Yuri	Max-Planck-Institut für Mathematik, Germany
Moody, Robert V.	Dept. of Math., University of Alberta
Moser, Jürgen K.	Dept. of Math., E.T.H., Switzerland
Phong, Duong H.	Dept. of Math., Columbia University
Reid, Nancy	Dept. of Stat., University of Toronto
Vinet, Luc	Director

CRM/Fields Committee

According to the guidelines NSERC's Committee on Collaborative Special Projects (CCSP) sent to CRM and the Fields Institute after the review of their last application in 1994, the mandate of the CRM-Fields Institute Coordinating Committee is the following: *(i)* monitor the national impact of the CRM and the Fields Institute as research resources in the Mathematical Sciences and *(ii)* monitor and facilitate the coordination of activities between the two centres. The members of the CRM-FI Coordinating Committee are:

M. Boyer	CIRANO, Montréal
H. Brunner	Chair, Memorial University
J.B. Friedlander	University of Toronto
P. Goddard	Cambridge University, UK
M. Moore	École Polytechnique, Montréal
D. Rolfsen	University of British Columbia
G. Semenoff	University of British Columbia
J. Slonim	IBM Centre for Advanced Study, Toronto
J.G. Timourian	University of Alberta
H.C. Williams	University of Manitoba

RESEARCH PROGRAMS

Coherent states and generalizations
Twareque Ali

Twareque Ali's research during the past six years, much of it carried out in collaboration with J.-P. Antoine, Université Catholique de Louvain, Belgium and J.-P. Gazeau, Université Paris-7, has been in the area of square-integrable group representations and their applications to coherent states, quantization and wavelet analysis.

Basically, these collaborators have developed a far-reaching generalization of the concept of square-integrability of a group representation, based on a homogeneous space of the group. This notion unifies all the different approaches to the study of coherent states for locally compact groups found in the literature, the theory of frames in Hilbert spaces and the analysis of signals using wavelet-like transforms. It also make a connection between the method of geometric quantization and quantization using coherent states and Berezin's technique of quantization on Kähler manifolds. As a consequence of their generalized theory of square-integrability, it is possible to derive wavelet-like transforms using almost any locally compact group. These transforms can then be used to analyze functions on the group space or on homogeneous spaces — a fact that can be exploited to analyze signals realized as these functions. In quantization problems, their techniques allow for the use of general vector bundles, so that internal symmetries can be accounted for, and furthermore, many of the obstructions inherent in standard geometric quantization are eliminated.

Numerical methods for nonlinear hyperbolic systems
Paul Arminjon

P. Arminjon's main research interest lies in the domain of numerical methods for nonlinear hyperbolic systems, with applications to engineering problems in gas dynamics and electrostatics/electrodynamics. For transonic/supersonic compressible flows, P. Arminjon studies, with his collaborators, A. Dervieux and M.C. Viallon, the design and numerical analysis of high accuracy finite difference, finite element or finite volume methods, and their application to typical flows arising in aerodynamics and aerospace engineering. Recently, they have obtained a family of non-oscillatory 2nd-order accurate schemes based on: i) a 2-step finite volume Richtmyer-Galerkin scheme with a TVD-controlled artificial viscosity, ii) a TVD-controlled barycentric combination of the Richtmyer-Galerkin and Osher's first order scheme, iii) a 2nd-order version of Osher's scheme using MUSCL-extrapolated, TVD-controlled, cell-interface flux values, and iv) a new finite volume extension, for 2-dimensional conservation equations, of the Nessyahu-Tadmor non-oscillatory 1-dimensional centred difference scheme.

In joint work with M.C. Viallon, they have recently proved the convergence of this latter scheme for a linear conservation equation, and they are presently extending the proof to the nonlinear case.

Nonlinear delayed equations
Jacques Bélair

Nonlinear dynamics gives an interpretation of complex changes in physiological rhythms (as bifurcations) when the values of the control parameters are modified. The theory leads to predictions for the possible behaviours in experimental settings and gives a unified explanation for the various regimes. Bélair's work has concentrated on nonlinear delayed feedback in control and in hormonal and neuromuscular system oscillations, stressing the role of the delay, the multiple feedback loops and the variable delays in the generation of periodic (oscillatory) or irregular behaviours.

Recent work has also applied a technique to detect the onset of single- or multiple-frequency periodic rhythms to 'simple' systems of artificial neural networks (of low dimension), as well as to a prototype of the simplest plausible oscillator in neuromuscular control. This same approach is currently used to design a controlled release drug administration system.

Algebraic transformation groups and algebraic geometry
Abraham Broer

Abraham Broer is interested in connections between algebraic geometry and representation theory. He studies, for example, nilpotent varieties and cotangent bundles of flag manifolds and common generalizations; algebraic properties like normality and rational singularities are established.

He proved a vanishing theorem for the higher cohomology of line bundles on the cotangent bundle of a flag manifold for the purpose of proving that the

subregular nilpotent variety is normal. Applications are in rings of differential operators and representation theory of Hecke-algebras.

He recently obtained another vanishing theorem, this time of the Dolbeault cohomology of homogeneous vector bundles on flag manifolds, generalizing Borel-Weil's vanishing result for ordinary sheaf-cohomology. It is expected to have applications in algebraic geometry.

Control and nonsmooth analysis
Francis Clarke

An important question in control addresses the stabilization of a system through a feedback command. In particular the following question is central: given that the system is commandable, is there an associated feedback? This question has important consequences in applications of control systems. When the system is linear, it is a classical result that the commandability implies stabilization through feedback. In the nonlinear case, the question remained long unresolved until recently when F. Clarke, in collaboration with Yu. Ledyaev, E. Sontag and A. Subbotin, answered it positively. A key point in their analysis is a new definition of a system solution whenever the feedback command is a discontinuous function.

Shape optimization, intrinsic differential geometry and the theory of thin shells
Michel Delfour

The main theme of Michel Delfour's research program is the optimization with respect to the shape or the geometry of a domain on which one or a system of partial differential equations are defined. This is a central problem in optimal design (aeronautics, heat control, image processing, etc.). At the theoretical level it is necessary to introduce appropriate topologies on families of subsets to give a meaning to derivatives and problem formulations. These include those induced by the distance functions or families of functions parametrized by sets and embedded in a functional space. In particular the algebraic distance gives a powerful tool to do differential calculus on submanifolds. This yields a totally intrinsic approach to the theory of thin shells and extends the shape calculus to differential equations defined on these submanifolds.

Biorthogonal wavelets
Gilles Deslauriers

David Donoho has used dyadic interpolation to generate wavelets. There exists a relationship between splines and wavelets. It is then possible to construct compact support wavelets with a given number of vanishing moments that are orthogonal to wavelets obtained from spline functions. Gilles Deslauriers' research project pursues, in this context, a recent idea on the lifting of wavelets.

Estimation in statistics and in actuarial studies
Louis Doray

Louis Doray's research deals mainly with two themes. In general insurance, his interests lies in modelling damages that were incurred but not reported to the insurer (IBNR) using regression models, time series and compound Poisson processes. He studies various parameter estimators, the adjustment of the model and the reserve prediction for IBNR accidents.

In statistics, he is interested in families of discrete laws defined on the nonnegative integers whose probability function can be expressed recursively. Some of these functions do not have a closed form. The estimation of parameters by the maximum likelihood method is then very difficult. However the iterated weighted least square method gives very efficient estimators that are easier to calculate. Moreover a statistic to test the adjustment of the model to data can be easily obtained, as well as its asymptotic distribution. Tests differentiating the various members of the family are being analysed. Doray is also studying the problem of the explicative variables for these discrete law families.

Analysis of curve and surfaces
Serge Dubuc

Serge Dubuc's main goal has been the development of mathematical analysis for the design, construction and perception and for the study of various planar and spatial figures such as curves and surfaces. Two themes are under study. *Iterative interpolation:* simultaneously with other authors, Dubuc invented a new technique of interpolation, the iterative interpolation (or fractal interpolation) in one or several variables. For the case of one variable, this technique is very close to the theory of wavelets. Dubuc is plan-

ning to develop further the multidimensional interpolation on rectangular and triangular lattices. Many irregular surfaces obtained in this context are difficult to study. *Analysis of fractal objects:* the aim of this theme is a better understanding of the theory of fractional dimensions. One subject of interest is the errors made in calculating the dimension of a regular object. Dubuc hopes to determine the dimension of certain lattices of curves that way.

Stochastic processes in actuarial studies and in finance
Daniel Dufresne

Daniel Dufresne's recent research can be divided into the following three topics: *(i)* Asiatic options, *(ii)* properties of gamma laws and *(iii)* the application of the theory of martingales to the general principles of actuarial evaluation.

(i) An Asiatic option is on the average of the values of a financial title (e.g. a share of IBM). Mathematically, the problem consists in finding the law of the geometric brownian motion average. No exact form is known for this law. Dufresne obtained this year new results concerning a famous identity due to Bourgerol, closely related to the average mentioned above. A simple proof was found for this identity.

(ii) New affine properties for gamma and beta laws were found. These results are important in the study of various stochastic difference equations that are used in actuarial studies and finance.

(iii) One can show that actuarial gains and losses that are studied in actuarial practice are in fact differences of martingales. This leads to better understanding of the behaviour of the actuarial surplus or deficit in time and can even influence the way actuarial evaluations are done.

Fractional generalization of the KdV equation
Stéphane Durand

Using supersymmetry it is possible to generalize in a non-trivial way the Korteweg-de Vries equation (KdV) to an integrable system of two coupled differential equations (Mathieu). Knowing that the supersymmetry can itself be extended (parasupersymmetry and fractional supersymmetry (Durand, Vinet)), it is natural to look for generalizations to integrable systems of several coupled differential equations. The formalism of fractional superspace introduced by Durand allows such a generalization in a natural way. This result is reached using the fractional extension of supersymmetry, the hamiltonian structure of the fractional pseudo-classical mechanics and the fractional generalization of superextension of Virasoro algebra (and/or its q-deformations).

Values omitted by classes of univalent functions
Richard Fournier

Richard Fournier and his collaborator (St. Ruscheweyh) are working at describing explicitly the values omitted by various normalized classes of univalent functions on the unit disk in the complex plane. It seems that these values might be described in simple terms by certain combinations of Taylor coefficients of the functions. Moreover it appears that the omitted values characterize, in a certain sense, various classes of univalent functions, for example the convex ones. This work had led to new inequalities on Taylor coefficients and the modulus of convex conformal transformations. It is hoped that these results can be used to solve some problems on homographic transformations of convex univalent functions.

Critical points of multivalued functionals
Marlène Frigon

The theory of critical points of univalent and continuously differentiable functionals and the multivalent analysis are two important and active topics in mathematics. Marlène Frigon's work is concerned with the development of the theory of critical points for multivalent functionals. This theory will then be applied to partial differential inclusions.

Image processing & target recognition applied to aerial surveillance
Langis Gagnon

Langis Gagnon and two students of Jiri Patera assess and devise new methods in image processing and target recognition for radar and infrared images. The goal is to develop a ship recognition system starting from a set of sensors mounted on an airborne platform. The algorithms studied here use various modern techniques of information processing like mathematical morphology, wavelets and artificial neural networks. Recent accomplishments include: *(i)* a study

of a new method for reducing the speckle noise in images from synthetic aperture radar (SAR) in "stripmap" mode using the wavelet transform and *(ii)* the target segmentation in a SAR image in "spotlight" mode.

Approximation in complex analysis
Paul Gauthier

Walsh has shown that any continuous function on a curve without double points in the complex plane can be approximated by complex polynomials. Thomas Bagby, Aurel Cornea and Paul Gauthier have shown a similar result using harmonic polynomials. Any continuous function on a curve without double points in Euclidean space can be approximated by harmonic polynomials. We are working on determining whether a similar result holds for functions defined of hypersurfaces.

Applications of wavelet transform and artificial neural networks
Bernard Goulard and Jean-Marc Lina

Bernard Goulard and Jean-Marc Lina are currently in the last year of a three year R&D NSERC collaborative project whose purpose is to extend the capability of Atlantic Nuclear Services monitoring and diagnostic systems through research and development of its Artificial Neural Network (ANN) technology and through the introduction of wavelet transforms in its signal processing parts. First, in collaboration with Y. Bengio (Département d'informatique et de recherche opérationnelle, Univ. de Montréal) and a student, F. Gingras, they are putting the finishing touches to a modular ANN based on a "mixture of experts" to classify various regimes of a reactor. A gaussian modelling has been applied to the occurrence probability of data and to differentiation between typical and atypical data of a class. This "inference machine" has been successfully tested on both simulated and real (reactor) data. Second, mathematical properties of complex wavelets made explicit by J.M. Lina (symmetry minimizing the usual shift variance of real wavelets and complex nature making easier the use of the information carried by the phase to code transient signals) have been illustrated in two papers by J.M. Lina and two students, P. Drouilly and J. Scott. These properties have led them to extend the study of wavelets to the domain of 2-d signals, i.e. image processing (nonlinear regression based on wavelets, multiscale algorithms for digital imaging, multifractal analysis by wavelets). One of them (B.G.), in collaboration with R. Roy (Polytechnique) and a student (A. Qaddouri), is also investigating parallel iterative processes to solve the Boltzmann transport equations which govern neutron distribution in a reactor and their possible extension to other fields.

Symmetries and solutions of nonlinear systems
Michel Grundland

Michel Grundland's research in the last few years has dealt with symmetry-reduction methods and Riemann-invariant methods and their application to equations of nonlinear field theory, condensed matter physics, as well as fluid dynamics. The development of these methods has provided several new tools to study nonlinear phenomena in physics, especially those described by multidimensional systems of partial differential equations (pde) that were not solved by other methods (like inverse scattering). Grundland's research program can be divided into 4 projects:

(i) conditional symmetries for nonlinear pde systems;
(ii) comparison of the various methods based on Lie groups used to study pde's;
(iii) invariant solutions and partially invariant solutions of Navier-Stokes equations;
(iv) multiple Riemann waves for quasilinear pde systems and their relation to symmetry reduction methods.

Classical and quantum integrable systems
John Harnad

During the past year, John Harnad's main research interest were all related to the modern theory of integrable systems. The topics studied were:

(i) isospectral deformations and classical R-matrices,
(ii) isomonodromic deformations and applications and
(iii) quantum integrable systems.

A recent work, in collaboration with A.R. Its, carries on the study of dual isomonodromic deformations but also initiates a new program relating the latter to computation of correlation functions in integrable quantum and statistical models and the spectral distributions of random matrices, in which a special class of Fredholm integral operators arise, whose Fredholm determinants are the correlation functions in question. These are computed through the Riemann-Hilbert problem "dressing method," adapted to the case of

isomonodromic deformations, leading to integral representations of importance in the calculation of asymptotics of such correlation functions. A key result derived in this work is the fact that the "dual" isomonodromic representations, deduced generally from the *R*-matrix structure, follow in this context from the invariance of the Fredholm determinant under Fourier transform of the integral kernel.

Geometry and physics
Jacques Hurtubise

Jacques Hurtubise' research work deals with geometrical and topological aspects of objects originating from mathematical physics. His projects are divided into two rather disjoint topics.

The first one studies the relationship between the solution spaces of several field equations of mathematical physics like those of the sigma model or Yang-Mills equations, and the functional spaces in which they lie. The questions are mostly topological in nature, like the proof of topological stability theorems. These theorems have been extended this year to the most general case known today. The solution spaces are here characterized as minima or critical sets of an action functional, and the techniques used in the proofs involve also analytic subtleties from the calculus of variations.

The second one addresses the algebro-geometric properties of completely integrable mechanical systems. An invariant has been recently introduced that allows for a measurement of the complexity of a large number of these mechanical systems; whenever this complexity is minimal, the system possesses very natural coordinate systems that seem to be related to its quantization.

Geometry of partial differential equations / quasi-exactly solvable systems
Niky Kamran

Niky Kamran's research deals with the properties of partial differential equations (pde) whose nature is essentially geometric. Some of the most important questions arising for pde's can be studied in a precise way in combining classical analytic techniques and powerful tools from differential geometry, differential topology and the theory of representation. Kamran's recent work has addressed global existence of variational principles, geometric integrability questions of hyperbolic equations, existence of conservation laws and singularity formation in solutions. Kamran has also contributed to the development of rigorous foundations for the theory of quasi-exactly solvable potentials in quantum mechanics using original cohomological methods together with fundamental theorems of the classical theory of invariants.

Boundary conditions for finite statistical models
Robert Langlands and Yvan Saint-Aubin

Robert Langlands and Yvan Saint-Aubin are trying to better understand the relationship between boundary conditions and partition functions of simple statistical models. Their aim is to obtain a description sufficiently precise to be able to obtain the partition function on a given (finite) lattice starting from the partition functions of two complementary sublattices. A first step has been accomplished by Langlands for the free boson theory: he constructed an application from the space of boundary conditions into the Hilbert space describing the model. An effort is now being made to construct a similar application for the Ising model. These problems are part of a larger program to define finite statistical models (i.e. with a finite number of degrees of freedom) that have a renormalization transformation and a non-trivial fixed point under this application. Such a family exists for percolation and the critical exponents for the simplest model in this family, calculated numerically, are very close to the critical exponents obtained through physical arguments.

Symmetry classes of polyominoes
Pierre Leroux

Polyominoes are important combinatorial structures for mathematical physics. They appear naturally in polymer models and the study of percolation. Recent work of the Bordeaux and Australian schools have given an enumeration with respect to area, perimeter and other finer parameters, for many classes of polyominoes having minimal convex properties. In a geometrical or combinatorial context, it is natural to consider convex polyominoes up to a symmetry or a rotation, i.e. as objects free to move in space. Pierre Leroux is currently working at enumerating them. This uses the study of orbits under the action of the dihedral group on convex polyominoes and, due to the Burnside lemma, the enumeration of various symme-

try classes of polyominoes. Many of these classes are intimately related to certain classical families of discrete models in statistical mechanics. For example, the class of convex polyominoes with a diagonal symmetry is related to that of directed and convex polyominoes (or animals) with compact diagonal source.

Analysis of population genetic models
Sabin Lessard

Sabin Lessard's research interests include a wide variety of population genetic models and the concomitant evolutionary dynamics. His ultimate goals are: a) to explain the maintenance of variability in biological populations, b) to develop mathematical and statistical techniques to analyse population genetic structures, c) to deduce general evolutionary principles, and d) to study populations with complex interactions between individuals.

q-special functions / The Efimov effect
Jean LeTourneux

Most special functions of mathematical physics admit q-analogs, namely deformations involving a parameter q. Just as Lie algebras provide a unifying framework for discussing special functions, q-deformations of these algebras provide a unifying framework for discussing q-special functions. In collaboration with Luc Vinet (CRM) and Roberto Floreanini (Trieste), Jean LeTourneux carries out a systematic investigation of the quantum algebraic interpretation of the q-special polynomials encompassed in the scheme of Askey-Wilson polynomials.

According to the Efimov effect, a three-body system has an infinite number of bound states when it involves two-body interactions that marginally bind the two-body system. Formal proofs of this effect are too complex to provide any physical intuition. Simpler proofs, given for special cases within the framework of the Born-Oppenheimer approximation, break down as soon as one goes beyond the lowest order approximation. With Bertrand Giraud (Saclay) and Yukap Hahn (Univ. of Connecticut), Jean LeTourneux investigates a certain number of questions raised by this situation.

Optimal methods of statistical modelling
Brenda MacGibbon

Brenda MacGibbon's main research interest is the optimal estimation of constrained parameters and its application to both parametric and non-parametric models of real life problems. She is particularly interested in the use of tools from harmonic analysis such as Fourier and wavelet analysis in functional estimation, for example:

(i) often there is a need to consider discrete data as in binary 0-1 signals or in the count data observed in many problems in positron emission tomography;

(ii) in random censorship-truncation models, in cancer trials, only incomplete data is available;

(iii) with econometric data and many biometric applications, prediction is important;

(iv) how may these techniques best be used for regression smoothing of binary data in small area estimation in complex sample surveys?

Numerical studies of wave perturbation interaction and shear flows in aerodynamics and geophysics
Sherwin Allan Maslowe

Chonghui Liu is currently simulating the transition toward turbulence of a limit layer. The important case is when the flow is subject to an adverse pressure gradient. This is the case, for example, in the neighbourhood of a flow stripping point around an incident wing profile. A spectral element method is used in order to combine the advantages of finite element methods (adaptability of the geometry) and the fast convergence of a spectral method. L. Campbell, a master's student, is currently studying the interaction of a forced wave packet of the Rossby type with the zonal shear flow in the framework of the beta plane often used in meteorology. This study will use asymptotic methods as well as finite differences. Its goal is to generalize the preceding studies by considering a wave packet instead of a normal mode. The recent analysis of the critical layer for a wave packet of Maslowe, Benney and Mahoney (1994) will play an important role here.

Nonseparable wavelets in 2-d
Michel Mayrand

Wavelets are used in signal processing in several ways (filtering, noise removal, compression, etc.). For 2-d signals (e.g. in imaging), tensor products of 1-d wavelets (separable wavelets) have been used until recently. However the most efficient wavelets in one dimension are those that exhibit symmetry properties. Since 2-d separable wavelets are not symmetric under the trivial transformations like rotation, it is natural to introduce new families of nonseparable wavelets. Michel Mayrand is currently working on defining new nonseparable wavelets and classifying their symmetry properties. As in the 1-d case, it will be useful to parametrize the 2-d wavelets according to their properties of orthogonality, of symmetry and continuity of their derivatives.

Non-crystallographic root systems
Jiři Patera

Jiři Patera's recent research has been devoted to two areas: *(i)* non-crystallographic root systems and *(ii)* deformations of semisimple Lie algebras and their representations. In collaboration with R.V. Moody (Alberta), he has laid down the mathematical foundations of non-crystallographic root systems, stressing their relationship with quasicrystals. Their consequences should be visible in publications over the next few years. A considerable effort was devoted to preparation and running of two events (jointly with R.V. Moody): a NATO Advanced Study Institute entitled "Mathematics of Aperiodic Long Range Order" and a semester program around the same subject (both held at the Fields Institute). He has also pursued the study and exploitation of simultaneous deformations of semisimple Lie algebras and their representations. The main tool here is the approach which he has invented recently, requiring that a fixed grading be preserved during the deformation.

Estimation of the precision matrix
François Perron

François Perron's research interests are related to decision theory and multidimensional analysis. His results are concerned with finding minimax estimators for the estimation of the average vector and the covariance matrix for a multinormal population. The idea underlying the finding of minimax estimators is the following. In general, an estimator never gives the exact value of the parameter it is supposed to estimate. There is always an error associated with the estimator precision and this error varies with respect to the value taken by the parameter to be estimated. For a given estimator, one can find the largest estimation error by varying the parameter on its domain. The minimax estimator is the one that gives the smallest maximal error. Krishnamoorthy and Gupta have tried to show, without success, that a certain estimator of the precision matrix was indeed minimax. In fact, they noticed through simulations that the result was plausible and formulated a conjecture that they believed to be true. In the paper *On a Conjecture of Krishnamoorthy and Gupta,* Perron has shown that the conjecture as stated is false even though the estimator of the precision matrix is indeed minimax. Perron's future projects will be related to Bayesian analysis and Monte Carlo simulation methods.

Clones and their applications
Ivo Rosenberg

Ivo Rosenberg has carried on the study of clone lattices (in universal algebra and multivalent logics) mostly on finite universes. He has studied maximal subclones of clones of isotone operations with respect to a bounded order, and clones that are not finitely generated. The clone network can be partitioned in a countable set of intervals called monoidal. For a universe of three elements, Fearnley and Rosenberg have undertaken a classification of these intervals by their size (1, finite, countable or with the cardinality of the continuum). Rosenberg showed the natural correspondence between hyperalgebras on an universe A and the subclones of the clone of isotone operations on the universe of nonempty subsets of A ordered by inclusion. He has started the classification of maximal subclones of this clone for finite A. In this correspondence, hypergroups become particular semigroups and Rosenberg is currently applying the results of the theory of semigroups to hypergroups. With Hikita he has also worked on a general criterion for completeness of uniform delay operations.

Qualitative study and bifurcations in differential equations
Christiane Rousseau

One of the long-term goals of Christiane Rousseau's research program is the completion of the

proof for the existence part of Hilbert's 16th problem for quadratic systems, i.e. to show that there exists a uniform bound for the number of limit cycles in a quadratic system. This project, initiated in 1991 with F. Dumortier and R. Roussarie, is progressing steadily. An important step made recently by Rousseau and H. Zoladek by exploiting simultaneously Khovanskii and Bautin's techniques for the centres and Roussarie's techniques for blowing up of families, allows one to hope for a complete solution in the coming three to five years.

All the techniques introduced here have an intrinsic interest going far beyond their application to the above problem. With Roussarie, Rousseau has applied some of them to the study of certain homoclinic loops in 3-dimensional space and their Ph.D. student, L.S. Guimond, is making further progress in that direction.

Another aspect of Rousseau's research project will be devoted to algebro-geometric methods applied to the study of polynomial vector fields. She is working on the problem of the centre (in collaboration with D. Schlomiuk) and on the geometric characterization of isochrone vector fields (with P. Mardešić and L. Moser-Jauslin).

This study of polynomial vector fields has a direct impact on still another aspect: the study of singularities of vector fields of higher codimension (typically larger than or equal to 3). The bifurcations of these singularities are organizing centres of bifurcation diagrams occurring in many applied models.

Algebraic theory of discrete structures
Gert Sabidussi

Gert Sabidussi's research interests lie in the algebraic theory of discrete structures, in particular graphs, his two main research axes being two algebraic structures associated with graphs: graph symmetries as expressed by the automorphism group, and invariants of certain groups of linear transformations induced by the graph. Under the first heading (symmetries), his research deals with algebraic properties of several classes of highly symmetric graphs that have their origin in theoretical computer science where they model the interconnection networks in parallel computing. These models exist in large number, giving rise to an abundance of different algorithms for a given task. The algebraic theory aims at reducing this profusion by laying a theoretical basis for the design of general algorithms applicable to all interconnection networks with a sufficiently rich symmetry structure. Under the second title (invariants), his research is less oriented towards applications and addresses mainly the relationships between chromatic properties of graphs and the existence of certain types of invariants.

Biomathematics and sociolinguistics
David Sankoff

In biomathematics, David Sankoff works on algorithms for the analysis of DNA sequences and he has, within the context of the human genome project, extended this discipline to the development of methods for studying genome evolution resulting from the process of chromosomal rearrangement. This has resulted in the development of algorithms (in collaboration with John Kececioglu and Gopalakrishnan Sundaram) for sorting permutations using a small set of operations: reversals, transpositions, translocations. Sankoff and Vincent Ferretti study syntenic sets of genes in collaboration with Joseph Nadeau, a geneticist at Case Western Reserve, and several mathematics and statistics students. In phylogeny, Sankoff and Ferretti have developed a method of nonlinear phylogenetic invariants.

In sociolinguistics, David Sankoff directs a programme whose goal is a rigorous statistical methodology for the analysis of syntactic variation and phonology in spoken language, based on computerized transcriptions of corpora of free speech. With David Rand, he developed and distributed a software package (GoldVarb) for linguistic data analysis. His empirical interests include bilingual syntax, specifically methods for distinguishing alternating borrowing codes, and the study of particles of speech.

Local and global studies of analytic vector fields
Dana Schlomiuk

Using interdisciplinary methods, Dana Schlomiuk is constructing various tools adapted to the global analysis of polynomial dynamical systems in the plane. Joining concepts from algebraic geometry and the theory of bifurcations, methods are being constructed that allow a better understanding of the global geometry of systems and leading to a better organization in the bifurcations arising in families of dynamical systems. Dana Schlomiuk's work, done alone or in collaboration with J. Pal or Y. Dupuis, gives a

good description of the global dynamics of certain classes of quadratic nonlinear systems. The methods developed are well suited for the problem of algebraic integrability of systems and further research is being pursued in that direction. Other aspects of the project cover the study of centre singularities (some work is in progress with L. Farell) as well as the gluing and resummation of local first integrals around a singularity or global ones.

Multi-sensor data fusion
Elisa Shahbazian

Elisa Shahbazian is responsible for conception, prioritization, and coordination of all R&D activities at Lockheed Martin Electronic Systems Canada (LMESC). LMESC is a leader in the integration and management of complex programs and systems. These systems require applications of Image Analysis and Data Fusion technologies for enhancing their decision aid capabilities by: (a) integrating information from multiple dissimilar sources to derive maximum information about the phenomenon being observed (Level 1 of Data Fusion or Multi-Sensor Data Fusion); (b) to evaluate/make inferences about the meaning of this phenomenon (Level 2 and 3 of Data Fusion or Situation and Threat Assessment); and (c) to propose actions that should be taken in the evaluated situations (Level 4 of Data Fusion and Resource Management).

Elisa Shahbazian leads a team of 10 scientists specializing in various areas of Data Fusion and Image Analysis and a team of engineers who build the high performance computer infrastructure necessary to demonstrate the enhanced decision aid capabilities for the complex programs and systems of interest to LMESC.

Elisa Shahbazian's current research activities fall within the field of Multi-Sensor Data Fusion (MSDF) and analyses/selection of MSDF techniques and architectures for integration into existing systems, where data management is performed using conventional techniques.

MSDF is one of the key future technologies whose applications can range from the military to the commercial, from computer vision and medical diagnostics to smart structures and image recognition for space satellites, and to surveillance, search and rescue.

As a technology, MSDF is actually the integration and application of many traditional disciplines and new areas of engineering to achieve the fusion of data. These areas include communication and decision theory, epistemology and uncertainty management, estimation theory, digital signal processing, computer science and artificial intelligence. Methods for representing and processing data (signals) coming from dissimilar sensors are adapted from each of these disciplines to perform data fusion.

Nonsmooth analysis: theory and applications
Ronald Stern

The field of nonsmooth analysis, pioneered by F.H. Clarke in the 1970's, provides a "calculus" for functions which are nondifferentiable and possibly not even continuous, and which are therefore not amenable to treatment by standard (i.e. smooth) methods. On the geometric side there have been many important applications of this theory in recent years, notably in optimization, control, and general dynamical systems (invariance theory and existence of equilibria). Ron Stern, in collaboration with F.H. Clarke, Yu. S. Ledyaev, P.R. Wolenski, and J.J. Ye, has been contributing in these areas in recent years. At present, a general problem Stern is working on is the construction of control feedback laws in certain control problems, using the tools of nonsmooth analysis.

Quantum integrable systems
John Toth

John Toth's principal area of research is the semiclassical spectral asymptotics of quantum integrable Hamiltonians. In particular, his work focuses on pointwise bounds for joint eigenfunctions, in terms of fractional powers of the semiclassical parameter. He is also working on analogous bounds for Toeplitz eigenfunctions on compact, CR manifolds.

The relevant techniques involve microlocal, Carleman-type estimates for the F.B.I. transforms of eigenfunctions.

Data fusion
Pierre Valin

Pierre Valin's main research interest is multi-sensor data fusion.

Data fusion coming from dissimilar sensors allows for an optimal synergy leading to better tracking and an identification of the target that is faster and safer. Various algorithms for sensors of the Canadian frig-

ate are presently under consideration for the Canadian surveillance airplane Aurora (CP-140). Among the new challenges are:

(i) the presence of imaging sensors (infrared and synthetic aperture) that call for algorithms for shape recognition,

(ii) the presence of a higher rate of false contacts due to waves and

(iii) a usually higher density of targets.

Distinguishing and identifying several boats of various shapes in close formation on an agitated sea presents more difficulties than tracking well-separated airplanes in a blue sky.

Statistical and quantum field methods in solid state physics
Carolyne Van Vliet

Carolyne Van Vliet's recent research interests have been concentrated on the following two subjects: *(i)* development of kinetic equations for transport properties in solid-state systems, together with detailed computations of the electrical conductance in such systems and *(ii)* electrical current fluctuations (called "electrical noise") in small systems and devices.

All kinetic equations in statistical mechanics are based on two patterns. First, following Liouville and von Neumann, one considers all interactions and externally applied fields on the many-body level. While this requires a "rather complete" Hamiltonian for the whole system, the advantage is that the equations on this level are linear so that standard functional analysis applies. Second, in many cases, one can consider the behaviour of quasi-particles, such as "dressed electrons" which are virtually independent, a process started by Boltzmann. One particle energies are easily formulated but the ensuing kinetic equations are quadratic or higher order in the collision terms. New quantum versions of this approach were successfully obtained by Van Vliet and Vassilopoulos.

Short noise and thermal noise, and their combined effect in mesoscopic quasi-one-dimensional conductors, was investigated by Van Vliet and Sreenivasan. This research is on the very edge of current developments in ultra-small electronic conductors and devices. The first low frequency result was given by Landauer and Martin. We extended and improved an approximation first used by Kuhn and Reggiani, employing quantum-field methods, obtaining both equilibrium results and non-equilibrium results under applied fields valid up to a terahertz (10^{12} hz). Full agreement with low frequency formulas of Landauer and Martin is obtained.

Quantum physics and combinatorics
Luc Vinet

The main objectives of Luc Vinet's research projects are: *(i)* to develop the appropriate theoretical tools for solving important models of quantum many-body physics; *(ii)* to advance the theory of symmetric functions. Last year, in collaboration with his Ph.D. student Luc Lapointe, Luc Vinet made a major step towards obtaining an algebraic solution of the Calogero-Sutherland model, and in so doing proved longstanding conjectures on some of the most important symmetric polynomials in algebraic combinatorics. With Roberto Floreanini (Trieste) and Jean LeTourneux, Luc Vinet has pursued his systematic investigation of the quantum algebraic interpretation of q-special functions. He has also undertaken a study of difference equations form the symmetry point of view.

Lie symmetries of difference equations
Pavel Winternitz

Lie groups as symmetry groups of differential equations provide powerful tools for solving such equations, especially when combined with singularity theory and other attributes of modern integrability theory. Pavel Winternitz, together with Decio Levi (University of Rome III) and Luc Vinet, is developing a formalism that should be equally useful for treating difference equations. Two different approaches are being considered simultaneously. One applies to differential difference equations, involving both continuous and discrete variables. Transformations involving the continuous variables are treated via Lie algebras, the discrete ones are treated globally. In the second approach all variables are continuous, but their increments are discrete, i.e. differences figure instead of derivatives. The symmetry group is then constructed via "discrete prolongation" techniques, adapted from the usual Lie techniques used for differential equations. In order to recover all Lie point symmetries of a differential equation in the continuous limit, it turns out to be necessary to consider a much larger class of symmetries in the discrete case. They act simultaneously on the entire lattice, not just at one point.

Assessing the quality of bootstrap samples and estimates
Yannis Yatracos

Yannis Yatracos' research deals with the problem of estimation intrinsically associated with the bootstrap that gives motivation for the method to be used in evaluating the quality of bootstrap samples and estimates. For a large class of models it has been shown that, as the dimension d of the model increases, the quality of the sample obtained by resampling decreases compared with that of the original sample, and it is less probable that the bootstrap estimate will be close to the target. In particular, the quality of the sample obtained for the case of a uniform law is comparable to that of a sample from a model of infinite dimension. Finally measures are introduced to determine the efficiency of estimators obtained by resampling and the compatibility of different models with the resampling.

SCIENTIFIC ACTIVITIES

Theme Year 1995-1996: Numerical and Applied Analysis

CRM Summer School on Boundaries, Interfaces, and Transitions

6-18 August 1995, Banff (Alberta)

Org.: Michel Delfour (chair, CRM & Université de Montréal), John Chadam (Fields Institute & McMaster University), Michel Fortin (Université Laval), Augusto Visintin (Università degli Studi di Trento, Italie), Jean-Paul Zolésio (Institut Non Linéaire de Nice, France)

The themes of the CRM Summer School at Banff were shape and structural optimization (including microstructures), phase transition and moving boundary problems, numerical methods for the above types of problems. We were not able to cover everything and had to make choices. The choice of the topic was motivated by earlier cooperation between John Chadam and Delfour in the Summer 1990. Chadam was co-organizer of the International Meeting on Free Boundaries, and Delfour was the organizer of the NATO-ASI Séminaire de Mathématiques Supérieures on Shape Optimization and Free Boundaries. It was an attempt to bring together researchers from both communities and favour exchanges and collaboration in areas where the geometry, boundaries and interfaces play a central role. We feel that the experience was extremely successful and that the School (5 years later) confirmed this sentiment.

The use of the geometry in the design, identification and control of technological processes has been steadily increasing. Shape and optimal design have been concerned with the improvement and the design of mechanical parts (N. Kikuchi for the automotive industry). However other original applications appeared in image processing (Geman and Geman, Ambrosio, Richardson, Morel, Lions, etc.), composite materials, aerospace engineering (reservoirs with flexible membranes, shape control of parabolic antennas), etc. In other applications the geometry appears as a control variable as in "optimal swimming" and stabilization of membranes and plates by periodic variations of the boundary.

Geometric measure theory which has been extremely successful in the theory of minimal surfaces is now widely used in Shape optimization. In the same direction the recent work on Motion by Mean Curvature, Hysteresis problems, etc., clearly provides fundamental tools which can be used in other contexts.

The School was primarily aimed at Ph.D. students in their final years and recent Ph.D.'s. Its objective was to give a broad introduction to contemporary problems where the geometry or the structure is a key variable in the understanding, modelling and control of physical and technological systems and problems, and to expose the participants to some of the latest developments in the associated Mathematics, Mechanics, and Physics.

It covered selected aspects of shape optimization and optimal design, mathematical models in material sciences, hysteresis, superconductivity, phase transition, moving boundary problems, and some of the associated numerical issues.

In addition to the 9 main speakers, we had 5 young, outstanding Canadian speakers (3 are women) to complement and expand the lectures of the main speakers. Six special talks were also given in the afternoon seminar. The main speakers (6 hours) and their title were: John Chadam (McMaster Univ. and Fields Institute), *Reactive Flows in Porous Media*; Alain Damlamian (École Polytechnique, France), *Variational approach to the Stefan problem and extensions to the phase field model with constraints*; Michel Delfour (CRM & Univ. de Montréal), *Introduction to shape and geometric optimization*; Ingo Mueller (Technische Universität Berlin), *Mechanics and thermodynamics of phase transitions in shape memory alloys*; Jacob Rubinstein (Technion, Israel), *Mathematical models in superconductivity*; Mete Soner (Carnegie Mellon, USA), *Front propagation and phase field theory*; Claudio Verdi (Università di Milano, Italy), *Numerical analysis of geometric motion of fronts*; Augusto Visintin (Università degli Studi di Trento, Italy), *Models of Hysteresis*; Jian-Jun Xu (McGill), *Interfacial Instabilities, Pattern Formation and Selection*.

The other speakers (2 hours) and their title were: Anne Bourlioux (CERCA & Université de Montréal), *Detonation and propagation of shocks*; Lia Bronsard

(McMaster University), *Interface dynamics as singular limits of Ginzburg-Landau equations*; Katie Coughlin (CERCA & Université de Montréal), *Transition to turbulence*; Robert Guénette (Université Laval), *Numerical analysis of viscoelastic fluids and liquid crystals*; Michael Ward (Univ. of British Columbia), *Dynamical Metastability and Singular Perturbations*.

The six special talks (1 hour) were: Toyohiko Aiki (Gifu University, Japan), *One-phase Stefan problems for semilinear parabolic equations*; Changfeng Gui (Univ. of British Columbia), *A three layered minimizer in triple phase transition*; William D. Kalies (Georgia Institute of Technology), *On the asymptotic behaviour of a phase-field model for elastic phase transitions*; Nobuyuki Kenmochi (Chiba University, Japan), *Attractors for non-isothermal models of phase transitions*; Robert E. O'Malley, Jr (Chiba University, Japan), *Supersensitivity of shocks and transition layers for certain singularly perturbed boundary value problems*; Hong-Ming Yin (University of Notre-Dame, USA), *A free boundary problem describing a chemical diffusion process with localized reaction*.

The lecture notes of the CRM School will appear in the CRM Proceedings and Lecture Notes Series published by the AMS. In addition a book by C. Verdi has been accepted in our Monograph Series.

Numerical Methods for the Euler and Navier-Stokes Equations

Organized in collaboration with CERCA
14-16 September 1995, Hotel Bonaventure/Hilton, Montréal
Org.: Paul Arminjon (chair, CRM & Univ. de Montréal), Alain Dervieux (INRIA, France), Michel Fortin (Univ. Laval, Québec), Wagdi G. Habashi (Concordia Univ. and CERCA)

The aim of the conference was to bring together some of the leading specialists in the field of numerical methods for the Euler and Navier-Stokes equations, and to give a comprehensive survey of recent developments in high resolution methods (finite differences, finite elements, finite volumes) for compressible and incompressible flows. A wide range of numerical experiments with numerous applications to engineering problems was presented and discussed.

The total number of registered participants was 75 and the high quality of the speakers led to a clear and interesting exposition of many of the most important aspects of recent research in computational fluid dynamics, with a strong emphasis on compressible flows and applications to aerodynamics.

A large number of advanced Ph.D. students (35) participated in the conference, and several of them mentioned they were very pleased to attend lectures of the highest standard which were at the same time well structured, clearly presented and included interesting recent developments in numerical methods for the Euler and Navier-Stokes equations as well as a large number of numerical applications to real engineering problems. Among those many applications, we should mention: A. Jameson (aerodynamics consultant for major American aircraft manufacturers), A. Dervieux, O. Pironneau, B. Stoufflet (aerodynamics consultants for Dassault Aviation and Aerospatiale, France), B. van Leer, E. Tadmor, E. Turkel, H. Yee (consultants for the NASA), S.K. Godunov (formerly a main scientific consultant for computational aerodynamics to the Russian airplane and space programs), M. Fortin and W.G. Habashi (consultants for Hydro-Quebec and Pratt and Whitney, respectively).

The series of lectures addressed five fundamental aspects of research in Computational Methods for the Euler and Navier-Stokes Equations.

Numerical methods for the Euler equations. R. Abgrall (INRIA) presented his work with A. Harten on Multiresolution Representation in Unstructured Meshes, a technique for representing data which originate from discretization of functions in unstructured meshes in terms of their local *scale* components, by means of a nested sequence of discretizations. A. Dervieux (INRIA) described two strategies, based on Mixed Finite Element – Finite Volume methods, to attenuate or completely avoid spurious numerical diffusion (derivation of a higher-order dissipation or construction of flow dependent finite volume partitions). M. Hafez (U. of California, Davis) presented some anomalies associated with the non-uniqueness of the numerical solution of the Euler equations. B. van Leer (University of Michigan) discussed interesting issues associated with operator splitting and staggered grids, and presented his joint work with E. Turkel on a comparison of preconditioning methods (for both for Euler and Navier-Stokes). E. Tadmor (Tel Aviv University and U.C.L.A.) described his one-dimensional non-oscillatory central differencing scheme where Riemann problems at the cell interfaces are bypassed by using two alternate grid systems (joint work with H. Nessyahu). X.D. Liu (Courant Institute for Mathematical Sciences, NYU), in joint work with P.D. Lax, introduced a new positivity principle for numerical schemes for hyperbolic systems, and presented a fam-

ily of space and time - second order accurate schemes with a very simple structure using characteristic decomposition. Comparison with well-established methods showed that the new schemes are competitive.

Numerical methods for the Navier-Stokes equations. M.J. Ivanov (Central Institute of Aviation Motors, Moscow) described recent CFD developments and applications for steady and transient flows in different types of turboengines and their components. O. Pironneau (Université Paris VI and INRIA) spoke on wall laws for turbulent flows, which are extensively used to eliminate from the domains of computation regions of strong gradients or regions where the geometry is complex. He gave an interpretation of wall laws by domain decomposition, of error estimates for approximations on a simple potential flow with complex boundaries, and presented several test cases for turbulent flows. B. Stoufflet (Dassault Aviation) outlined recent efforts and improvements to remedy the deficiencies of numerical methods when implemented in industrial codes, and to insert those methods as efficient tools and analysis algorithms in the process of numerical shape optimization. H. Yee (NASA-Ames) reported on super-stable implicit methods and time-marching approaches, showing how the use of dynamical system theory can contribute to reliability, efficiency, stability and convergence properties of time-dependent approaches for obtaining steady-state numerical solutions (joint work with P.K. Sweby).

Multidimensional algorithms. P. Arminjon (Université de Montréal) presented a two-dimensional finite volume extension of the Lax-Friedrichs and Nessyahu-Tadmor schemes (joint work with M.C. Viallon, Univ. de St-Etienne), with several applications to typical 2-dimensional problems (on unstructured grids). H. Deconinck (Vrije Universiteit Brussel) reported on compact multidimensional upwind schemes for the Euler equations on unstructured meshes, showing the relation with finite element methods and other distribution schemes by reuniting them as Fluctuation-Splitting schemes (joint work with H. Paillère). C. Hirsch (Vrije Universiteit Brussel) presented some multidimensional upwind algorithms for the Euler and Navier-Stokes equations, using a cell-centred finite volume approach on structured grids, leading to first and second order accurate schemes with respectively minimum and zero cross diffusion (joint work with P. van Ransbeeck). R.J. LeVeque (University of Washington) described a three-dimensional algorithm for general hyperbolic systems of conservation laws, consisting of an unsplit finite volume method based on solving one-dimensional Riemann problems on piecewise constant states rather than interpolated values, and then using the waves arising from this solution to define second order correction terms; the waves are further split by solving Riemann problems in the transverse direction to model the cross-derivative terms (joint work with J.O. Langseth).

Grid generation and mesh adaptation. W.G. Habashi (Concordia University / Pratt and Whitney) presented an edge-based mesh adaptation procedure using mesh orientation and stretching, and based on error estimates and mechanisms to recast the mesh according to these error estimates. Numerous numerical tests gave good evidence of the efficiency of the method (joint work with M. Fortin and the two authors' student teams at Concordia and Laval University). S.K. Godunov (Russian Academy of Sciences) one of the pioneers in Computational Fluid Dynamics, described his joint work with V.M. Gordienko and G.A. Chumakov on the theory of two-dimensional quasi-isometric grid construction.

Present status, Challenges and Future in CFD. Finally, A. Jameson (Princeton University), in the last lecture, gave a remarkable survey of the role of computational fluid dynamics as a tool for aircraft design. Addressing the requirements for effective industrial use, and the trade-offs between modelling accuracy and computational costs, he discussed the main issues in algorithm design, together with a unified approach to the design of shock capturing schemes. He then described his use of techniques drawn from control theory to determine optimal aerodynamics shapes, concluding that, in the future, multidisciplinary analysis and optimization should be combined to provide an integrated numerical design environment.

Semi-analytic Methods for the Navier-Stokes Equations

Organized in collaboration with CERCA
2-6 October 1995, CRM
Org.: Katie Coughlin (CERCA & Univ. de Montréal)

This workshop was held as part of the CRM thematic year on Numerical Analysis, Approximation Theory, and Applications, and was one of three held in the fall on numerical methods in fluid dynamics. Thirty-one participants attended, coming from

Canada, the U.S., Europe and Asia. Being a somewhat specialized subject, the workshop was organized to be small-scale and informal, with each invited speaker giving two hours of lectures, leaving plenty of time for interaction. The attendance was divided about fifty-fifty between mathematicians and physicists. An effort was made to encourage attendance by researchers and students in Montréal.

The goal of the workshop was to bring together researchers from different disciplines, who share an interest in developing innovative methods for the solutions of partial differential equations, primarily (but not exclusively) the equations describing fluid motion. The particular issue that arises in this context is the coexistence of coherent, structured flow on large scales with apparently random fluctuations on small scales. For computational methods to resolve exactly all the important scales is generally impractical, and so one wants to develop methods which treat the small scales by a statistical model and retain the more-or-less exact dynamics at large scales. This idea has proven to be quite difficult to implement in a well-defined way, suggesting that much of the physics and mathematics of the "apparently random fluctuations on small scales," and how they affect the large scale motion, is not well understood. Each of the invited speakers contributed a different perspective to this basic problem of interaction between large and small scales.

The topics selected were divided into three general themes: physical fluid dynamics and physical modelling; statistical approaches and modelling of data; and the theory of inertial manifolds applied to computational techniques.

In the first category, Phil Marcus (U.C. Berkeley) and Jeff Weiss (U. Colorado) spoke about geophysical fluid dynamics, in which one commonly sees the formation of large "coherent structures" (such as the Red Spot of Jupiter, or the Gulf Stream) in a turbulent background. They emphasized that often the physical processes leading to structure formation can be understood with relatively simple models, even though a complete mathematical description is lacking. Tom Warn (McGill) spoke about the difficulties of developing rigorously consistent models of turbulence. Katie Coughlin (U. de Montréal) discussed the particular problems associated with transitional flows, for which there is a temporal as well as spatial intermittency to the turbulence. Charles Meneveau (Johns Hopkins) discussed large eddy simulations of turbulent flows, which model the effect of small scales by an average taken along a fluid particle path line.

In the second category, Emily Ching (CUHK) presented a theoretical analysis of the statistics of passive scalar fluctuations, with comparison to experiment. S. Balachandar (U. Illinois) discussed a statistical technique for extracting coherent features from velocity data, which can be used for example to compare structures in different physical situations. Henry Greenside (Duke University) discussed various attempts to quantify pattern order and disorder in convection calculations, using ideas taken from statistical and condensed matter physics. Michael Kirby (Colorado State) presented an innovative technique for constructing low dimensional models of PDE's by training a neural net with numerical data. Nadine Aubry (CUNY) presented an extension of the Karhunen-Loève decomposition, a technique which decomposes a random field into a set of modes which is optimal in the energy norm, to space and time dependent fields.

In the third category, Edriss Titi (U.C. Irvine) presented an overview of the theory of inertial manifolds and the related nonlinear Galerkin numerical methods, and discussed results which suggest that they may provide a framework for understanding finite dimensional behaviour in the Navier-Stokes Equations. Martine Marion (Lyon) presented a finite element algorithm for the equations on an approximate inertial manifold, along with error estimates and different implementations. John Heywood (UBC) pointed out that improved error estimates for nonlinear Galerkin methods may be attributed to a reduction in the severity of the Gibbs phenomena, and that one should be careful in giving physical interpretations of the theory. He also presented a new adaptive Fourier spectral method developed for 2D forced flows.

Overall, the response of the participants (most of whom were unfamiliar with the work of about one half of the other attendees) to the broad range of disciplines represented was very enthusiastic. The mathematicians were interested to see how much could be learned by physical reasoning, and the physicists found the discussion of basic mathematical problems to be very illuminating. The two-hour format was also well-received, as it allowed a thorough presentation of each speaker's material. Thus, as a forum for the exchange of scientific ideas, the workshop was very successful.

Numerical Methods in Fluid Mechanics

Organized in collaboration with CERCA
13-22 November 1995, CRM
Org.: Alain Vincent (CERCA & Univ. de Montréal)

The goal of this workshop was to bring together during two weeks the top world experts on current numerical methods in fluid mechanics. The lectures were presented at the level of graduate students, researchers and engineers. The 60 or so participants were from universities in Montreal but also from Canada, Europe and North America.

The following themes were covered.

New numerical techniques for environment study. Jean Cote (RPN, Montreal, Canada) gave a lecture on the computer code "Global Finite Elements" currently in testing for numerical weather forecasting at Environment Canada. The code uses the semi-Lagrangian method that leads to better time stability. Sylvie Gravel (RPN, Montreal, Canada) presented the principal problems related to semi-implicit and semi-Lagrangian schemes. David Dritschel (Cambridge University, UK) gave two lectures on contour dynamics. This numerical method leads to a very precise resolution of vorticity filaments and can be used for simulations of the stratospheric polar vortex for example. A new method for continuous remeshing using a calculation of the coordinate system metrics was used to study the dynamics of tornadoes by Brian Fiedler (University of Oklahoma). This method offers an interesting alternative to industrial automatic remeshing codes. Ue-Li Pen (Princeton) uses a very similar method to describe astrophysical flows. Ue-Li and Brian were able to compare their algorithms during the workshop and the technique developed independently for astrophysical problems appeared to be more powerful.

Closure techniques for simulation of turbulent fluids are divided into two categories: large eddy simulation (LES) and Reynolds stress tensor modelling. The state of the art for LES was described by Joel Fertziger (Stanford). In particular he mentioned a LES model for flows around buildings. The modelling of the Reynolds stress tensor was detailed in a series of 5 lectures by Brian Launder (Manchester). These methods, more complex but also more precise than the "k-epsilon" method, are starting to be used in industry.

Methods to deal with discontinuities. Charles Hirsch (Vrije Universiteit, Bruxelles) spoke about shock capturing schemes and of new multidimensional upwind schemes that seem to be very powerful. Stanley Osher (UCLA, Los Angeles) described essentially non-oscillatory schemes (ENO) for the combustion case. Maurice Meneguzzi (IDRIS, Paris) uses these methods for the simulation of two-phase fluids (e.g. water and oil) that are important for the oil industry. The water-oil interface is treated as an internal boundary. The internal boundary techniques are also active topics of mathematical research. Alfio Quarteroni (Cagliari, Italy) gave a series of lectures on domain decomposition methods.

Finite difference methods can also be used for high precision calculations by using compact schemes. Sanjiva Lele (Stanford) presented us some of their applications in engineering.

Finally, Claude Basdevant (Ecole Normale Superieure, Paris) talked about **wavelet methods for the resolution of PDE's**. These questions are still open and, for the time being, the applications are limited to the one-dimensional Burger equation.

The audience was larger than foreseen, forcing us to change the conference hall at the last minute. The courses were most appreciated. Even the Masters students were able to learn something about these advanced subjects. Not only did it provide an opportunity for young researchers to meet the leaders of the subject, but it also allowed time to develop a professional relationship with them.

Spline Functions and the Theory of Wavelets

22 January- 12 April 1996, CRM
Org.: Martin Bilodeau (Université de Montréal), Gilles Deslauriers (École Polytechnique, Montréal), Serge Dubuc (Université de Montréal), Véronique Hussin (Université de Montréal), Jean-Marc Lina (CRM & Université de Montréal), Brenda MacGibbon (UQAM), Marc Moore (École Polytechnique, Montréal), Sherman Riemenschneider (University of Alberta)

Ten workshops on spline functions and the theory of wavelets took place at the CRM during the winter semester. The emphasis was on recent developments in both theoretical aspects and applications, particularly on curve and surface modeling. Among the theoretical aspects was an up-to-date presentation of

splines in one and several variables. The applications, beside numerical imaging and interpolation, were signal processing, numerical solutions of differential equations, fractal geometry, and other applications to physics and statistics. Work done in Edmonton and Montreal was thoroughly discussed. The workshops brought together mathematicians, computer scientists, engineers, physicists and statisticians. Unusual for a mathematical meeting were the presence of professionals from the film and animation industry, optometrists, meteorologists, telecommunication scientists, and even one economist. The fact that the subject of wavelets is particularly popular in France, the United States, and Canada was an asset for the organization of the workshops and a factor in their scientific success. The ties among Canada, the United States, and France were reinforced through these meetings.

There were, in total, 89 one-hour lectures and 39 half-hour communications. The average size of the audience was around 30 participants. The Aisenstadt lectureship was held by Prof. Yves Meyer, and a very faithful audience of over one hundred attended his 5 lectures. (See description in the section Chaire Aisenstadt.) Three discussion sessions were organized on geometric modeling, multifractal applications, and wavelets in physics. A video of a conference by Daubechies was presented and two participants gave software demonstrations. Finally two of the participants gave a lecture for undergraduates in the weekly series of the Département de mathématiques et de statistique of the Université de Montréal.

The countries represented were Canada (31), the United States (38), France (21), Germany (7), Argentina (3), Switzerland (3), Australia (2), Belgium (2), Chile (2), Croatia (2), the Netherlands (2), Japan (2), England (1), Cyprus (1), Scotland (1), Israel (1), Poland (1) and Russia (1). To these one must add fifty-eight local participants.

In total the workshop represented 47 days of activity with, on average, 3 lectures per day. This relaxed format allowed for a high level of interaction and met with unanimous approval.

A particular effort was made to maximize the benefit of the workshops for Canadian students. During the fall of 1995, a course on splines and wavelets was given at the graduate level. Around twenty Canadian students received a stipend to attend the workshops and to give lectures on their work.

The one-hour lectures will be collected in a proceedings if the material proves sufficiently original. The refereeing committee will be made up of Alain Arnéodo, John Benedetto, Hermann Brunner, Stéphane Jaffard, Alain Le Méhauté, Brenda MacGibbon, Sherman Riemenschneider, and Philippe Tchamitchian. Publication is currently set for the end of 1997. The Aisenstadt lectures given by Prof. Meyer will be published separately by the AMS in the CRM Proceedings and Lecture Notes.

Geometric modeling of splines (22-26 January). Surface modeling using spline functions was the main subject of this workshop. Several applications were presented: fabric texture representation (J.P. Dussault, Sherbrooke), cornea modeling for diagnostic purposes in optometry (B. Barsky, UC at Berkeley), rigid structures and surface intersections in architecture (T. Grandine, Boeing Comp. Services). A roundtable brought together people from various horizons: mathematicians interested in surfaces, computer scientists working in the film industry (more precisely at Softimage), engineers working on airplane modeling at Boeing or on image processing through telecommunications.

Splines for approximations and for differential equations (29 January - 2 February). Two approaches were discussed here. The first one stressed the use of one- and two-variable functions in approximation problems. The second one presented the efficient application of splines to the solution of differential equations. In particular, H. Brunner (Memorial) presented an excellent overview of the latter, covering the main results of the last twenty years or so. Two researchers from Croatia also gave relevant lectures.

Splines and wavelets (12-16 February). This workshop acted as a bridge between the first two and the one that followed, on the theory of wavelets and their applications. Six leaders in the field of two-variable wavelet theory and applications and multivariate splines (Micchelli, Goodman, Riemenschneider, Chui, Ron, and Ward) were among the lecturers. Prof. Chui also gave the CRM-ISM Colloquium.

Wavelets and approximation (19-23 February). Nonlinear approximations through wavelets was the dominant theme during this workshop which was directed primarily by De Vore. As was pointed out by B. Lucier (Purdue), this subject is extremely popular, in particular due to the decision of the FBI to use wavelets in fingerprint compression. The importance of Besov spaces in approximation theory was also stressed. D. Hardin (Vanderbilt) pre-

sented a recent construction of "intertwined" multiresolution analysis that enhanced the reputation of the group at Georgia Tech that discovered it. Other conferences covered the resolution of hyperbolic equations and multivariate wavelet approximation.

Multiresolution analysis and subdivision operators (26 February - 1 March). Multiresolution analysis is at the heart of the theory of wavelets. It was discussed by, among others, Cohen (Univ. Pierre et Marie Curie), who won the Popov Prize for his work in approximation theory. Dyn (Tel Aviv) presented subdivision schemes that have important applications in curve and surface generation by computer. This workshop was very popular with graduate students; five of them also presented their recent results.

Wavelets and differential equations (4-8 March). The importance of wavelets in the solution of pde's is being increasingly recognized and this workshop provided an opportunity to survey their various uses. France and Germany were well represented. Several discussions on approaches to numerical solution of pde's took place between the American school (represented by G. Beylkin (Colorado)) and the French one (P. Tchamitchian (Aix-Marseille), V. Perrier (Lab. de Météorologie Dynamique-ENS, Paris), J. Liandrat (Marseille)). Elliptic, hyperbolic, and parabolic pde's were covered as well as nonlinear equations such as those of Burger and Kuramoto-Sivashinsky. Turbulence was discussed by M. Farge (ENS, Paris) and M. Wickerhauser (Washington Univ.).

Wavelets in signal processing and image analysis (11-15 March). With the explosion of telecommunications and numerical image analysis, wavelets became powerful tools in the field of signal processing, even before the word "wavelet" was coined by Meyer. This workshop attracted the largest audience. It coincided with the Chaire Aisenstadt held by Meyer himself. His main topics were multifractal analysis, microlocal analysis, Mallat's algorithm (often used in image analysis), and the Marseille algorithm for the detection of chirps and fractionnary brownian motion. Due to the wide spectrum of applications to image analysis and to physics, a large audience attended the entire series of lectures. The workshop also offered other exceptional lectures. D. Donoho (Stanford) presented schemes of nonlinear refinement for signal statistical analysis. G. Strang (MIT), Kovasevic (AT&T-Bell Labs), Benedetto (Maryland) and S. Myers (IBM) also made important contributions. The topics ranged from voice recognition and detection of early signs of epileptic seizures to filters and image analysis. The speakers also included engineers form Toronto, scientists from the Centre for Research in Communications located in Ottawa, and scientists from Australia.

Wavelets and fractals (18-21 March). Very often in fractal geometry can one witness a multiresolution analysis intimately tied to wavelet theory. One of the leaders in this field, S. Jaffard (Créteil) has shown that the coefficients of the wavelet expansion give the fractal dimension of the set of singular points of a function. These fundamental results show the importance of wavelet multifractal analysis. This was the central theme of the workshop. A. Arnéodo (CNRS-Bordeaux) gave an interesting application of wavelets to DNA chains.

Wavelets in physics (25-29 March). Quantum mechanics had an impact early in the development of wavelets, and it was natural that this workshop should start with a detailed presentation of this subject (T. Ali (Concordia)). G. Battle (Texas A&M) explored this theme further in quantum field theory. Other subjects in physics were also touched upon: multifractal formalism applied to turbulence and to cluster growth may be among the most exciting. A. Arnéodo, J. Muzy (CNRS-Bordeaux) and S. Jaffard gave a detailed account of the formalism with its thermodynamical correspondence. J.P. Antoine (Louvain-la-Neuve) presented recent applications in solid state and atomic physics.

Splines and wavelets in statistics (8-12 April). Statisticians often use powerful tools based on spline functions and wavelets. Statistics, on the other hand, also raises new questions about these tools. Johnstone (Stanford), Houdré (Atlanta) and von Sachs (Kaiserlautern) discussed several uses of wavelets for data analysis with noise. A. Anroniadis (IMAG, France) and N. Heckman (UBC), among others, showed that splines often lead to better estimation of parameters. J. Ramsay (Florida) expanded on several statistical problems related to emission tomography.

Artificial Neural Networks (ANN)

15-30 April 1996, CRM

Org.: Yoshua Bengio (Univ. de Montréal), Renato de Mori (McGill Univ.), Bertrand Giraud (CEA, France), Bernard Goulard (CRM & Univ. de Montréal)

The workshops on artificial neural networks (ANN) were aimed at providing a state-of-the-art survey of the field. These activities were devoted to the theoretical aspects (statistics and learning) during the first week, and then to the structure and applications to signal processing (in one and two dimensions). The present workshop was a natural complement to the several workshops on wavelets of the thematic semester. Its program was intended to clarify the relationship between ANN-statistics (early workshops) and the wavelets-statistics relations that were discussed in the final workshop on wavelets. Discussions of ANN's in finance (last two days) produced a natural transition to the workshop on the Mathematics of Finance (see below).

Several topics were vigorously debated. On the theoretical side, the question of how to control the problem of over-generalization was raised. After an introduction of the subject by Yoshua Bengio, Frederico Girosi and Vladimir Vapnik, two viewpoints were presented, namely that of regularization and that of automatic control of capacity. Another theoretical idea (though close to applications) appeared repeatedly: the use of a set of models for the reduction of the variance of the generalization error (Yoshua Bengio, Jean-Pierre Nadal, Nathan Intrator). It was stimulating to hear rather different viewpoints expressed by physicists, computer scientists, and statisticians during the question periods.

On the applications side, several practical uses of ANN's were discussed by Marco Gori, Bertrand Giraud, Simon Haykin, Hervé Bourlard, Michael Mozer, Patrice Simard, Yann Le Cun and Paul Refenes. Marco Gori gave a presentation on a laptop computer of a recognition system for license plates. Many new algorithms were presented, such as those of Geoff Hinton and Peter Dayan (Helmholtz' machine), Samy Bengio (Markov models of input-output), Michael Jordan (graphical models), to name only a few. More specialized communications were also presented: on cognitive psychology and reinforcement algorithms (Jordan Pollak, Sue Becker, Geoff Hinton, Fernando Pineda, Michael Mozer), implementation on chips (Hans Peter Graf, Jocelyn Cloutier), and financial applications (Yoshua Bengio, Paul Refenes, René Garcia).

The number of participants during the two weeks was ninety. The audience was larger than expected and required a last minute change of conference hall. Many of the participants commented on the high level of the conference. Several discussions led to new collaborations, in particular with P. Refenes (London School of Economics), K. Muller (GMD-FIRST-Berlin) and B. Giraud (Physique théorique-Saclay), and probably many others.

Mathematics of Finance

Organized in collaboration with CIRANO

30 April - 3 May 1996, CRM

Org.: Jérôme Detemple (CIRANO & McGill Univ.), Daniel Dufresne (CRM & Univ. de Montréal), Éric Ghysels (CIRANO & Univ. de Montréal), Martin Goldstein (CRM & Univ. de Montréal)

Advisory Committee: Luis Caffarelli (I.A.S.), Darrell Duffie (Stanford), Ioannis Karatzas (Columbia), Stanley Pliska (Univ. of Illinois at Chicago)

Sponsors: AMI Associés Inc., Bourse de Montréal, Caisse de Dépôt et Placement du Québec, Hydro-Québec

Theory of Nonlinear Special Functions: The Painlevé Transcendents

13-17 May 1996, CRM

Org.: L. Vinet and P. Winternitz (CRM & Univ. de Montréal)

This workshop was the first of a "tandem" of two, both devoted to quite recent developments in special function theory. The second, (reviewed separately), concerned q-special functions, satisfying linear equations. All speakers were invited to participate in both meetings; quite a few of them did.

The Painlevé transcendents were introduced at the turn of the century, specifically to solve a certain class of second order nonlinear ordinary differential equations. More specifically, P. Painlevé and B. Gambier identified all equations of the form $\ddot{y} = P(x, y, \dot{y})$, where the right hand side is rational in y and $\dot{y}$ and analytical in x, having what is now called the "Painlevé property." This means that the general solution of the equation is single valued in the neighbourhood of any one of its "movable" (i.e. depending on initial conditions) singularities. Fifty classes of such equations were identified and six of them turned out to be irreducible: their general solution cannot be expressed in terms of previously known functions, like elliptic functions, or solutions of linear equations.

During the last 30 years or so, since the development of soliton theory and more generally the modern theory of infinite-dimensional integrable systems, the Painlevé transcendents have become extremely important. They occur as solutions of a very large class of physical problems, coming from nonlinear optics, wave propagation in fluids and plasmas, quantum field theory, statistical mechanics and many others. The problems are described by integrable partial differential equations. The Painlevé transcendents occur as special solutions, usually particularly stable ones, providing the asymptotic behaviour for solutions of large classes of Cauchy problems.

The aim of the workshop was to bring together experts in a booming field of research, either to give review talks or to present new and important results. The speakers succeeded in doing this to a remarkable degree. New results were presented in the context of a review of the field. This brings us to the second goal of the workshop: i.e., to introduce participating students, postdoctoral fellows, and interested scientists from related fields to the subject and to produce a book based on the talks presented. Such a book is in preparation and should serve as a multiauthored monograph on a well focused branch of applied mathematics and theoretical physics.

The Workshop on Painlevé Transcendents had 36 registered participants. They came from 12 countries (13 from Canada, 4 each from the USA and Japan, 3 from France, 2 each from Australia, Italy, Poland and the United Kingdom, 1 each from Belgium, Mexico, Taiwan and Russia). The speakers were, in alphabetical order, Yu. Berest (Canada), R. Conte (France), B. Dubrovin (Italy), A.S. Fokas (U.K.), J. Harnad (Canada), A. Its (USA), N. Joshi (Australia), A.V. Kitaev (Russia), M.D. Kruskal (USA), V. Matveev (France), M. Musette (Belgium), F.W. Nijhoff (U.K.), K. Okamoto (Japan), A. Ramani (France), C. Rogers (Australia), V. Spiridonov (Canada), H. Umemura (Japan), P. Wiegmann (USA) and P. Winternitz (Canada).

A.S. Fokas presented a series of four lectures on the isomonodromy method for the solution of Painlevé equations and on specific physical problems leading to these equations. All other talks were one hour, leaving a lot of time for discussions.

The topics covered include: (1) discrete Painlevé equations, singularity confinement for solutions of nonlinear difference equations, asymptotics of discrete Painlevé equations, (2) Hamiltonian, R-matrix, isomonodromy and Riemann-Hilbert methods for studying properties of the Painlevé functions, (3) detailed asymptotics of the continuous Painlevé equations, (4) classical special solutions of the Painlevé equations, (5) physical applications of the Painlevé equations, (6) other topics, such as the relation to the classical problem of lacunas for linear hyperbolic equations, and the use of algebraic methods to study the Painlevé equations or to generate new equations with the Painlevé property.

Algebraic Methods and q-Special Functions

21-26 May 1996, CRM
Org.: Luc Vinet (CRM & Univ. de Montréal)

The following scientific report was written by Prof. Charles Dunkl and published in the "Newsletter of the SIAM Activity Group on Orthogonal Polynomials and Special Functions" (ed. Wolfram Koepf), June 1996, and posted on the electronic news net of this Activity Group (eds. T.H. Koornwinder and M. Muldoon).

Monday, May 20, was a national holiday in Canada (Victoria Day) and this pushed the start of the workshop to Tuesday morning. Luc Vinet, co-organizer with Pavel Winternitz and director of the Centre, opened the session at 9:00, welcomed the participants and dedicated the workshop to the memory of Waleed Al-Salam, who passed away April 14 of this year. There were approximately seventeen invited speakers who gave hourlong talks; there were about fourteen who contributed half-hour talks. David and Gregory Chudnovsky were invited but were unable to attend and their time on the program was taken by other events. Sergei Suslov was invited, could not attend, but Dick Askey delivered his lecture. Dick also gave his own lecture (more details later). There was indeed a heavy emphasis on q-special functions, both of one-variable Askey-Wilson type and of several-variable Macdonald type. The algebraic methods were highly refined and sophisticated, mostly based on root systems and associated mathematical objects such as double affine Hecke algebras.

Here is an alphabetical list of the invited speakers and the titles of their lectures:

George Andrews (Plane partitions and MacMahon's partition analysis), Richard Askey (An inequality of Vietoris and some related hypergeometric sums), Ivan Cherednik (Spherical difference Fourier transform), Charles Dunkl (Intertwining operators and polynomials associated with the symmetric group), Pavel Etingof (Macdonald eigenvalue problem and

representations of quantum $gl(n)$), Roberto Floreanini (Quantum algebras and generalized hypergeometric functions), Adriano Garsia (Polynomiality of the Macdonald q,t-Kostka coefficients: a short proof), Mourad Ismail (Moment problems and orthogonal polynomials), Tom Koornwinder (The A_1-tableau of Dunkl-Cherednik operators), Boris Kupershmidt (The great powers of q-calculus), Ian Macdonald (Symmetric and non-symmetric orthogonal polynomials), David Masson (Contiguous relations, continued fractions and orthogonality: a ten year journey up the Askey chart), Willard Miller, Jr. (Tensor products of q-superalgebras and q-series identities), Masatoshi Noumi (Raising operators for Macdonald polynomials), Eric Opdam (Spectral analysis of Hecke algebras), Siddhartha Sahi (Recent results on Jack polynomials and Macdonald polynomials), Dennis Stanton (q-orthogonal polynomials as moments), Sergei Suslo ([talk delivered by R. Askey] Some basic hypergeometric series and q-Bessel functions), Luc Vinet (Creation operators for Macdonald polynomials. Simple and simpler proofs).

Contributed talks were given by N. Atakishiyev, R. Chouikha, P. Floris, A. Grunbaum, K. Kadell, M. Kapilevich, J. LeTourneux, K. Mimachi, A. Odzijewicz, V. Spiridonov, A. Strasburger, N. Takayama, F. van Diejen, L. Vinet. Ian Macdonald started his lecture Tuesday morning and finished it on Wednesday. Dick Askey gave an extra half-hour talk on Wednesday containing an overview of Askey-Wilson polynomials. Tom Koornwinder used another one of the hours originally scheduled for the Chudnovsky's to discuss René Swarttouw's web site

`www.can.nl/~demo/CAOP/CAOP.html`

which gives access to a vast collection of formulas and references for the polynomials contained in the Askey tableaux ($q = 1$ and general q).

There were approximately sixty participants; as well some members of the Centre dropped in on the lectures. The languages spoken at coffee and in the hallways appeared to be English, Russian, French, Japanese, Dutch, Polish. The weather was mostly delightful with a few evening showers. The University is in a scenic location near the Mont Royal; the Pavillon André-Aisenstadt, which houses the Centre, is a beautifully designed and equipped academic building, with a wonderful view of the northwest of the city. Ian Macdonald gave the first lecture on Tuesday, Adriano Garsia gave the last one on Saturday, thus bracketing an intense period of leading-edge mathematics. It was generally agreed that the workshop was excellent both in organization and inspiration to the participants for future work. At the conclusion all applauded and thanked the organizers for this exciting conference.

Chaire Aisenstadt

The Chaire Aisenstadt was endowed by Montréal philanthropist Dr. André Aisenstadt. Under these auspices, one or two distinguished mathematicians are invited each year for a period of at least one week, ideally one or two months. During their stay the lecturers present a series of courses on a specialized subject. They are also invited to prepare a monograph. At the request of Dr. Aisenstadt, the first of their lectures should be accessible to a wide audience. Previous holders of the Chaire Aisenstadt are: Marc Kac, Eduardo Zarantonello, Robert Hermann, Marcos Moshinsky, Sybren de Groot, Donald Knuth, Jacques-Louis Lions, R. Tyrell Rockafellar, Yuval Ne'eman, Gian-Carlo Rota, Laurent Schwartz, Gérard Debreu, Philip Holmes, Ronald Graham, Robert Langlands, Yuri Manin, Jerrold Marsden, Dan Voiculescu, James Arthur, Eugene B. Dynkin, David P. Ruelle, Robert Bryant and Blaine Lawson. This year the CRM offered two Chaire Aisenstadt lectureships, both in close relationship with the semester on applied analysis; they were held by Y. Meyer and I. Karatzas.

Professor Yves Meyer
CEREMADE, Université de Paris-Dauphine
Time-scale and time-frequency analysis in signal or image processing
5 lectures, 11-15 mars 1996, CRM

Prof. Yves Meyer's lectures entitled "Time-scale and Time-frequency Analysis in Signal or Image Processing" were given during a semester focusing on spline functions and the theory of wavelets. An expanded version of these lectures will appear in the CRM Monograph Series published by the American Mathematical Society.

Professor Meyer occupies the position of "Professeur de classe exceptionnelle" at the Université Paris-Dauphine. Since 1991 he has been detached to the Institut Universitaire de France. He is also Membre de l'Institut (Académie de Sciences de Paris) and a foreign honorary member of the American Academy of Arts and Sciences. He has been awarded the following scientific prizes: Peccot (1969), Salem (1970), Carrière (1972), and the Grand Prix de l'Académie des Sciences (1984). He has given invited lectures at the International Congress of Mathematicians in Nice (1970), Warsaw (1983), and Kyoto (1990) as well as the International Congress of Mathematical Physics, Swansea (1988), and the International Congress of Applied Mathematics, Washington (1991).

Following his studies Professor Meyer worked at several universities in France, among them Strasbourg, Université de Paris-Sud, and the École Polytechnique, before accepting his current position. His recent research interests centre around the various aspects of the theory of wavelets, including the construction of orthonormal wavelet bases, image analysis, signal processing, and the equations of Navier-Stokes. In addition to numerous articles in these fields he has published a series of books on the diverse aspects of wavelet theory. He has also made significant contributions to the fields of algebraic numbers, harmonic analysis, and pseudo-differential operators.

Professor Meyer has directed some 30 Ph.D. students, organized several conferences, and edited various proceedings.

Professor Ioannis Karatzas
Columbia University
Lectures on Financial Mathematics
9 lectures, 6-27 May 1996, CRM

Ioannis Karatzas received his Diploma from the National Technical University of Athens in 1975 and then went to Columbia University for his M.Sc. and Ph.D. degrees, received in 1975 and 1980 respectively. After a postdoctoral year in Applied Mathematics at Brown University, he returned to Columbia where he is currently Eugene Higgins Professor of Applied Probability. His research interests have been in Probability and Mathematical Statistics, Random Processes, Stochastic Calculus, Stochastic Control and Optimization, and, most recently, Mathematical Economics and Finance.

Professor Karatzas has written 56 articles, several sets of lecture notes, and the well-known book "Brownian Motion and Stochastic Calculus," written with S.E. Shreve. Another book, entitled "Methods of Mathematical Finance," and coauthored by Shreve, is scheduled for publication in 1997. He is a fellow of the Institute of Mathematical Statistics and serves on the editorial board of several distinguished journals.

Professor Karatzas' Aisenstadt lectures were attended by an enthusiastic audience of mathematicians, economists, and workers in the field of finance. They will be published this fall by the AMS in the CRM Monograph Series under the title "Lectures on the Mathematics of Finance."

Extra-thematic Activities

CAMS Meeting

Memorial University, St. John's, Newfoundland
31 May - 2 June 1995
Sponsors: CRM, Fields Institute, Memorial Univ. (Vice-President/Research, Dean of Science, Dean of Graduate Studies, Dept. of Mathematics)

The well attended meeting was dominated by two special sessions reflecting current trends and activities in their respective fields, namely the special session "Numerical analysis of nonlinear differential and integral equations" (organized by Hermann Brunner) and the special session "Climate, meteorology, environment" (organized by Sam Shen, Univ. of Alberta).

The first of these special sessions involved seven invited speakers: Alastair Spence (Univ. of Bath, UK), Chris Budd (Univ. of Bristol, UK; now at Bath), Andrew Stuart (Stanford Univ.), David Sloan (Univ. of Strathclyde, Glasgow), Sue Campbell (Univ. of Waterloo), Yanping Lin (Univ. of Alberta), and Uri Ascher (Univ. of British Columbia). The topics of their talks ranged from differential-algebraic integral equations arising in the modelling of catalytic combustion, blow-up in semilinear parabolic PDEs, pseudo-spectral methods for singular problems to delay equations, Volterra integro-differential equations, and various aspects of deterministic and probabilistic computations for ODEs and PDEs. Judging from the reaction of the participants, these talks illuminated many of the current research activities in numerical nonlinear analysis, and they were well received because of their uniformly clear and thoughtful presentation. Moreover, they stimulated a series of follow-up discussions, both formal and informal, among a good number of the participants who benefited from the opportunity of having access to the wide variety of expertise of the speakers.

The second special session involved five invited speakers: Bryant Moodie (Univ. of Alberta), Paul Sullivan (Univ. of Western Ontario), Richard Greatbach (Memorial Univ. of Newfoundland), Gerald North (Texas A & M Univ.), and Sam Shen (Univ. of Alberta). Their lectures seemed an ideal complement to the previous ones and dealt with topics such as gravity currents, stability analysis for simple climate models, optimal estimation of global change in climate, the monitoring of dilution of contaminant concentration values, and the question "why is the North Pacific so different from the North Atlantic."

It appeared, judging from numerous comments received during and after the meeting, that the format of this year's CAMS meeting (where the emphasis was on carefully selected invited talks intended to introduce important current research and to stimulate discussion and possibly collaboration between researchers from different, and yet related, fields) was very successful: this format resembled more a workshop-like meeting than the "usual" conference with less focused talks spread over a wide area.

Theoretical and Mathematical Physics

at CAM-95
11-15 June 1995, Université Laval, Québec
Org.: F. Khanna (Univ. of Alberta), L. Vinet (CRM & Univ. de Montréal)

This conference took place during the Congress of the Canadian Association of Physicists (CAP). This Congress was a very important event: CAP celebrated there its 50th anniversary and invited important delegations of the American Physical Society and of the Sociedad Mexicana de Física so as to make this celebration a North-American event. The session sponsored by the CRM on Theoretical and Mathematical Physics reflected this desire to build on the ties that the Canadian community of theoretical physicists has with the United States and Mexico. It was also at the banquet of the Congress that the first CAP/CRM Award in Theoretical and Mathematical Physics was presented to Prof. Werner Israel of the University of Alberta. (See the CRM Prizes.)

The several topics covered at the conference are found among the most active disciplines in theoretical and mathematical physics in Canada: classical and quantum gravitation, quantum field theory, classical and quantum integrable systems and the use of symmetry in physics.

Classical and quantum gravitation. This section covered the whole spectrum of the modern problems in this field: the theoretical predictions of general relativity, its geometrical content, quantum gravity and measurements. The lecturers were: G. Kunstatter (Winnipeg), R. Laflamme (Los Alamos), A. Macias (Iztapalapa), T. Matos (IPN, San Pedro), L.O. Pimentel (Iztapalapa), E. Poisson (Washington), G.F. Torres del Castillo (Puebla), J.D. Vergera (UNA de México), H. Waelbroeck (UNA de México).

Quantum Field Theory. This section covered several aspects of quantum field theory: quantization schemes, conformal field theory, applications to nonlinear optics and to impurity problems in solid state physics, lattice models, relationship with statistical mechanics, etc. The speakers were: I. Affleck (UBC), D. Caenepeel (Montréal), A. Das (Rochester), R. Jackiw (MIT), A. Leclair (Cornell), P. Lepage (Cornell), E. Lieb (Princeton), R. Mackenzie (Montréal), P. Nelson (U. Penn.), P. Ramond (Florida), B. Sakita (City Coll. of CUNY), M. Shifman (U. Minnesota), T. Steele (Saskatchewan), J. Tuszynski (Alberta).

Classical and quantum integrable systems. Integrability is a rather recent subject that originated with the discovery of nonlinear pde's with some remarkable properties like superposition principles and elastic diffusion properties of some of their localized solutions. In less than thirty years it led to outstanding developments in one- and two-dimensional theoretical physics. The most active areas in this field were represented: spin chains and their algebraic structures, solution through algebraic methods, new algebraic structures like quantum groups, parafermionic algebras and Yangian structure, etc. The speakers were: H. Bougourzi (Montréal and Stony Brook), F.D. Haldane (Princeton), V. Korepin (Stony Brook), Hoong-Chin Lee (National Chung Hsing Univ.), P. Mathieu (Laval), Y. Saint-Aubin (Montréal), L. Vinet (Montréal), P. Wiegman (Chicago), Yong-Shi Wu (Utah).

Symmetry in physics. Symmetry and the underlying mathematical structures of groups and Lie algebras have been one of the most powerful tools of mathematical physics in this century. Several avenues that are currently being explored were reported on: the symmetries of differential and difference equations, calculatory aspects of representation theory of Lie algebras, aperiodic structures, etc. The lecturers were: W.E. Baylis (Windsor), R. Floreanini (Trieste), S. Hacyan (UNA de México), N. Kamran (McGill), M. Légaré (Alberta), L. Marchildon (UQTR), B. Mielnik (México and Warsaw), J. Patera (Montréal), D. Provost (Laurentian), M. Thoma (McGill), P. Winternitz (Montréal), K.B. Wolf (UNA de México).

Partial Differential Equations and Their Applications

12-23 June 1995, Fields Institute, Toronto
Org.: P. Greiner (Univ. of Toronto), V. Ivrii (Univ. of Toronto), L. Seco (Univ. of Toronto), C. Sulem (Univ. of Toronto)
Sponsors: Canadian Mathematical Society (CMS), CRM, Fields Institute, NSERC and the Department of Mathematics of the University of Toronto

This conference was the 1995 Annual Seminar of the Canadian Mathematical Society and had partial differential equations as its main theme. Its goal was to enhance interaction between PDE and a large number of different areas, such as arithmetic groups, spectral asymptotics, differential geometry, fluid dynamics and quantum physics. Its format consisted of five minicourses and a large number of lectures given by distinguished mathematicians, all of them world leaders in their field. The minicourse given by Charles Fefferman was part of the Fields Institute's Distinguished Lecture Series.

There were also two sessions of contributed talks, given by younger mathematicians. Graduate students from universities in Canada and elsewhere had the exceptional opportunity to attend courses and lectures given by scientists of outstanding stature and well-known for their original work as well as for their excellent presentations. Graduate students took a very active part in the conference. Indeed, some of them agreed to take on the challenging work of writing the notes for the lectures of the minicourse speakers. It is these notes, revised by the lecturer, that will be published in the Seminar Proceedings. The Proceedings are to be published by CRM.

The seminar drew the attention of graduate students and professional mathematicians from all over the world: there were participants from Austria, Israel, USA, France, England, Russia, Scotland, Spain, Italy, Sweden, Mexico, and of course Canada.

The CMS 1995 Summer Seminar resulted in a significant level of on-going collaborative activity. For example, Papanicolau and Sulem will be writing a book based upon their talks at the Seminar and Ron Howard, a student of Charles Fefferman (Princeton), is now working with Peter Constantin (Chicago). In addition, a remarkable amount of productive research took place during the actual Seminar.

It is also worth noting that participants included not only PDE experts, but algebraic geometers, number theorists, engineers, physicists, and some non-spe-

cialists. This helped to give those attending and the public in general a better view of Canadian mathematics and an area of significant research activity.

This workshop had 81 registered participants.

Nonlinear Dynamics and Time Series: Building A Bridge Between the Natural and Statistical Sciences

15-18 July 1995, CRM (Univ. de Montréal)
Org.: Colleen D. Cutler (Univ. of Waterloo), Daniel T. Kaplan (McGill Univ.)
Sponsors: Fields Institute and CRM

This workshop was a highly successful effort to bring together leading statisticians and physical/biological scientists working in the area of analysis of data from nonlinear dynamical systems and time series. The primary purpose of the workshop was to promote an exchange between these two groups, in the hope of encouraging further interdisciplinary research and communication. The new perspectives and methodology of time series analysis inspired by recent developments in nonlinear dynamics and "chaos" theory provide new viewpoints and open problems for statisticians; in return, applied scientists have much to gain from the expertise and long experience of statisticians in time series analysis and related areas.

The idea for the workshop originated with Dr. John Chadam, then director of the Fields Institute for Research in the Mathematical Sciences. Colleen Cutler and Danny Kaplan were approached to be co-organizers representing, respectively, statistics and dynamics, and the CRM agreed to co-sponsor, as well as host, the resulting workshop. The workshop was designed to follow some international statistical meetings being held in Montréal in mid-July.

The program consisted of 22 speakers from various countries, with approximately half being statisticians, and the remaining half being scientists working in nonlinear dynamics in mathematics, physics, or biology. Opening overview lectures were given by Professors Henry Abarbanel and Howell Tong, representing scientists and statisticians respectively. Topics covered at the workshop include problems and methodology related to embedding and reconstruction of dynamical systems from observed time series data, forecasting and prediction of nonlinear systems, error bounds and estimation of local Lyapunov exponents, performance of surrogate data techniques, separating deterministic and stochastic components in time series, nonlinearity and estimation for time series with long-range dependence, and ideas and techniques of chaos control.

Approximately 80 additional people attended and participated in the workshop; these participants represented a wide range of scientific disciplines, including mathematics, statistics, economics, physics, biology, geology, and engineering. Discussions and exchange at the workshop were lively and fruitful, and the program was deemed a success by speakers and participants alike.

Formal proceedings from the workshop are being published as a Fields Institute Communications volume, to appear in late 1996.

ICRA - Evolutionary Biology

22-27 August 1995, Val Morin (Québec)
Org.: David Sankoff (CRM & Univ. de Montréal)

About fifty researchers participated in this meeting, including about equal numbers of "Fellows" and "Scholars" of the programme such as David Sankoff, Robert J. Cedergren and B. Franz Lang of the Université de Montréal, their students and postdoctoral fellows, "Associés" of the programme from Québec, Canada, the United States and overseas, international advisors of the programme and invited speakers.

The colloquium's themes were mathematical analysis of genome rearrangements and algorithms for phylogeny. The invited speakers included the following individuals: M. S. Waterman (USC), J Felsenstein (U. Washington), P. Pevzner and S. Hannanhalli (Penn State and USC), J. Kececioglu (U. Georgia), M. Steel (New Zealand), T. Warnow (Penn), V. King (Victoria), E. Myers (Arizona), S. O'Brien (NIH), G. Olsen (Illinois).

Organic Mathematics Workshop

12-14 December 1995, Centre for Experimental and Constructive Mathematics (CECM), Simon Fraser University (SFU), Burnaby, B.C.
Org.: Jonathan Borwein (SFU)
Sponsors: CECM and CRM

The intention of the workshop was to explore the possibilities for activating mathematical papers by allowing for computation and other real-time enhancements. The workshop has led to a CMS Proceedings: an in-press volume which is the hardcopy version of the intrinsically electronic "Proceedings of the Organic Mathematics Workshop." The electronic version is available at: `www.cecm.sfu.ca/organics`

The more precise "raison d'être" of the Conference and the exact nature of the electronic proceedings are described in the accompanying articles:

- schedule of the meeting;
- list of speakers;
- abstracts of talk;
- budget summary;
- a detailed description of the project: What is organic mathematics?;

as are the many issues raised by such a project.

The conference was in purely scientific terms a huge success, both in the calibre of the science and the level of exposition. In addition, the technical staff at CECM provided a superb level of computational assistance with many of the talks being given "on-line."

The Web version of the Proceedings was released in April and has since been visited more than 2,200 times. It has been awarded several web recognitions (including "site of the week" in the Chronicle of Higher Education, three star status by Magellan and inclusion in the Scout Report).

The final question that begs to be asked is, why produce a "hardcopy" version at all. The primary answer is that conventional books still have a far larger potential audience and a clearer archival role. The centre piece of the Organic Mathematics Workshop is the content of the mathematical papers and is primarily text based. This book allows us to make these papers easily and comfortably available to a wide readership, not just those with fast internet access. Additionally this volume provides a fixed, and easily referenced, permanent version of what is otherwise an evolving document.

The process of turning a conference into a "virtual book" into a conventional manuscript has been interesting and has necessitated addressing a variety of additional issues. How does one include links? These we have included primarily as footnotes and appendices. A "book" has firm space limits and so some ancilliary material had perforce to be dropped. Colour pictures are expensive so most of these were also excluded. Some of the electronic features like video or interactive Maple sessions simply can't be reduced to text. The above exclusions in some ways diminish the collection but in other ways enhance it; principally by focussing on what is central, the mathematical content.

Also in this period of rapidly emerging evolving network technologies most of us are still most comfortable reading books not screens. Perhaps it will stay this way for quite a while.

Harmonic Analysis and Number Theory

In honour of Carl Herz (1930-1995)
15-19 April 1996, McGill University
Org.: J. Choksi (McGill), S. Drury (McGill), R. Gundy (Rutgers), R. Murty (McGill), N. Varopoulos (Univ. Paris VI)
Sponsors: NSERC, Fonds FCAR, CICMA, CMS, CRM

Carl Herz made fundamental contributions to mathematics, especially in analysis. Among these are results on spectral synthesis, the theory of A_p spaces, the H_p theory of martingales, atomic decompositions and more recently, analysis on Lie groups. His mathematical interests extended well beyond analysis into number theory, probability theory and representation theory.

This conference brought together mathematicians of international repute from Canada, the United States, France, Italy, Russia and Australia to talk about work which would have interested Herz. There were 20 talks in all, each of about one hour: there were 4 each on the first three days, 5 on the fourth day and 3 on the last day. The first talk, by Varopoulos, was on the work of Herz. The talks of Stein, Kenig, Lohoue, Cowling, Gundy and Figa-Talamanca dealt with topics heavily influenced by Herz. Of the other talks, those of Christ, Stroock, Havin, Kahane, Koosis, Malliavin and Toth all fell in the domain of analysis, many of them with at least some connection to harmonic analysis, those of Arthur, Sarnak, Boyd and Murty in the domain of Number Theory, that of Kamran on Lie groups and geometry, and that of Langlands on percolation and lattice systems.

We plan to publish the proceedings of the conference in a volume of the CMS Conference Proceedings. Participants as well as invited speakers may submit papers for publication. All submissions will be peer refereed. S. Drury and R. Murty will edit the Proceedings. N. Kamran and R. Murty are editors of the series.

Semidefinite Programming & Interior-Point Approaches for Combinatorial Optimization Problems

15-17 May 1996, The Fields Institute, Toronto
Org.: Joseph Cheriyan, Bill Cunningham, Levent Tunçel, Tony Vannelli, Henry Wolkowicz (Univ. of Waterloo), and Panos Pardalos (Univ. of Florida).
Sponsors: Fields Institute and CRM

Semidefinite Programming (SDP) is a generalization of Linear Programming (LP) in that the nonnega-

tivity constraints on the variables are replaced by a positive semidefinite constraint on matrix variables. Many of the elegant theoretical properties and powerful solution techniques follow through from LP to SDP. In particular, the primal-dual interior-point methods, which are currently so successful for LP, can be used to efficiently solve SDP problems.

In addition to the interesting theoretical and algorithmic questions, SDP has found many important applications in Combinatorial Optimization, Control Theory, Statistics, and other areas of Mathematical Programming. SDP is currently a very hot area of research. This can be seen by the number of talks on SDP at various recent optimization conferences and the number of recent publications.

The workshop attracted roughly 100 researchers. Participants from Australia, Austria, Brazil, Belgium, Canada, Israel, France, Hungary, Italy, The Netherlands, Puerto Rico, and USA gave the workshop an important international component. There were 39 talks during the three days of the workshop. A list of participants, speakers, titles, abstracts, and this article, can be found at:
`orion.uwaterloo.ca/~hwolkowi/fields.d/readme.html`
Following is a short, far from comprehensive, outline of several of the talks.

The workshop started with two talks on Matrix Completion Problems, i.e. under what circumstances does a partial matrix have a completion of a desired type. These problems have been studied extensively beginning in the early 80's and exemplify one of the early instances of SDP.

Monique Laurent spoke on "A Connection Between Positive Semidefinite and Euclidean Distance Matrix Completion Problems." Although there is a strong relationship between positive semidefinite matrices and Euclidean distance matrices, it was not clear how to link the two completion problems. Monique showed how the results for the Euclidean distance matrix completion problem can be derived from the corresponding results for the positive semidefinite completion problem, using a functional transform introduced by Schoenberg.

Charlie Johnson spoke on "Recent Progress on Matrix Completion Problems." After discussing the state of the art on positive definite completion problems, he continued with various other completion problems including those for totally positive matrices, P-matrices, inverse M-matrices, completely positive and doubly nonnegative matrices.

There were many talks on applications to Combinatorial Optimization. One of the main reasons for the current interest in SDP is the success in finding good approximations for the max cut problem. However, SDP has applications to many other combinatorial problems.

Stefan Karisch (with Franz Rendl) spoke on "Semidefinite Programming and Graph Equipartition." Stefan showed how SDP can be used to approximate the problem of partitioning a graph into equally sized components. Improvements were shown on previous eigenvalue approaches.

Christoph Helmberg (with Franz Rendl and R. Weismantel) spoke on "Quadratic Knapsack Relaxations Using Cutting Planes and Semidefinite Programming." Though the quadratic knapsack problem is extremely difficult to solve by linear programming alone, it was shown that SDP is very useful for quadratic knapsack problems.

Hsueh-I Lu (with Philip Klein) spoke on "Approximation Algorithms for Semidefinite Programs arising from Max Cut and Coloring."

Tamas Terlaky with J.P. Warners, C. Roos, B. Jansen) spoke on "Potential Reduction Algorithms for Structured Combinatorial Optimization Problems." Tamas presented a modified potential function, for binary feasibility problems that is computationally more attractive than the existing ones. A special class of binary feasibility problems were reformulated as nonconvex quadratic optimization problems. The reformulation is very compact. Computational results on several instances of the graph coloring and frequency assignment problem were presented. These results compared three different potential functions.

Qing Zhao (with Stefan Karisch, Franz Rendl and Henry Wolkowicz) spoke on "Semidefinite Programming Relaxations for the Quadratic Assignment Problem." Qing used the special structure of QAP to construct a gangster operator which enabled him to work in the minimal face of the feasible set. By exploiting this special structure and also using a conjugate gradient method, he was able to get strong bounds for the Nugent test set.

Many talks concentrated on Primal-Dual Interior-Point Methods for SDP. One of the reasons for the success of SDP is that interior-point approaches from LP can be extended to SDP; though the extension is not completely straightforward. Interesting complications can arise such as duality gaps, lack of strict complementary slackness, and confusing choices in the complementarity equations.

Kees Roos (with Tamas Terlaky and Etienne de

Klerk) spoke on "Initialization in Semidefinite Programming via a Self-Dual Embedding." In this way the initialization problem for semidefinite problems can be solved nicely. The method also provides a solution for the initialization of quadratic programs and it is applicable as well to more general convex problems with conic formulation.

Zhi-Quan Luo (with Jos F. Sturm and Shuzhong Zhang) spoke on "Superlinear Convergence of a Symmetric Primal-Dual Path Following Algorithm for Semidefinite Programming."

Michael J. Todd (with Kim Chuan Toh and Reha H. Tutuncu) spoke on "The Nesterov-Todd direction in semidefinite programming." Mike showed how to compute the direction efficiently and how to view it as a Newton direction.

Romesh Saigal (with Chih-Jen Lin) spoke on "An Infeasible Start Predictor Corrector Method for Semidefinite Linear Programming."

Shuzhong Zhang (with Jos F. Sturm) spoke on "Symmetric Primal-Dual Path Following Algorithms for SDP."

Yin Zhang spoke on "Infeasible Primal-Dual Interior-Point Methods for Semidefinite Programming." Yin presented formulations, or symmetrization schemes, for the complementarity condition to obtain square optimality systems so that Newton-type methods can be applied. He also discussed a complexity theorem for an infeasible, long-step, path-following algorithm and several computational issues with preliminary numerical results.

Several talks discussed the Geometry, Duality and Complexity of solving SDP:

Franz Renkl (with C. Helmberg) spoke on "Large Scale SDP using Eigenvalues." The advantage of this approach lies in the fact that extreme eigenvalues of symmetric matrices can be computed without having the matrix explicitly available.

Gabor Pataki spoke on "Cone-LP's and Semidefinite Programs: Geometry and a Simplex-type Method."

Motakuri Ramana (with Levent Tunçel and Henry Wolkowicz) spoke on "Strong Duality for Semidefinite Programming." Unlike LP, a duality gap can occur in SDP. Two approaches for closing the gap are compared and shown to have a common basis, though one is of polynomial size while the other is not.

Jos F. Sturm (with Zhi-Quan Luo and Shuzhong Zhang) spoke on "Duality and Self-Duality for semidefinite and Conic Convex Programming."

Laurent Porkolab (with Leoni Khachiyan) spoke on "Bounds on Feasible Solutions of Semidefinite Programs."

Lleonide Faybusovich spoke on "Infinite-dimensional Semidefinite Programming: Self-Concordant Barriers and Path-Following Algorithms for Semidefinite Programming."

Alexander Shapiro spoke on "Second Order Optimality Conditions and Stability Analysis of Semidefinite Programs."

Katya Scheinberg (with D. Goldfarb) spoke on "Interior Point Trajectories in Semidefinite Programming."

Manuel A. Nunez (with Robert M. Freund) spoke on "Condition Measures and Properties of the Central Trajectory of a Semidefinite Program." Manuel used Renegar's condition number to provide bounds on solution size and rates of change of solution. This shows that Renegar's condition number can greatly simplify sensitivity analysis for SDP.

Other applications of SDP were introduced and discussed. The wide ranging applicability, as well as fascinating and intriguing theoretical qualities, shows that SDP promises to be an active discipline of mathematical programming for many years to come.

Lieven Vandenberghe (with Stephen Boyd and Shao-Po Wu) spoke on "Determinant Maximization with Linear Matrix Inequality Constraints." This problem has many interesting applications including finding the ellipsoid of minimal volume that contains a given polytope or given points.

Arjan Berkelaar (with Shuzhong Zhang) spoke on "Convergence Issues and Path-following Algorithms for Semidefinite Programming." Arjan discussed convergence issues related to recent primal-dual interior-point algorithms for the monotone semidefinite linear complementarity problem.

Renato Monteiro "On Two Interior-Point Mappings for Nonlinear Semidefinite Complementarity Problems." Renato presented properties of two fundamental mappings associated with the family of interior-point methods for solving monotone nonlinear complementarity problems over the cone of symmetric positive semidefinite matrices. The first of these maps lead to a family of new continuous trajectories which include the central trajectory as a special case. The trajectories completely "fill up" the set of interior feasible points of the problem in the same way as the weighted central paths do the interior of the feasible region of a linear program.

Boris Mirkin "A Mine of Semidefinite Programming Problems"

In addition, Related Problems presented included:

Ding-zhu Du spoke on "On Floorplan Design and Optimization."

Jun Gu spoke on "Parallel Algorithms for Satisfiability (SAT) Problem."

Linas Mockus (with J. Mockus and A. Mockus) spoke on "Bayesian Approach to Combinatorial Optimization."

Mauricio Resende (with Panos Pardalos) spoke on "Using linear programming to help solve quadratic assignment problems." The linear programming problems used to obtain lower bounds for quadratic assignment problems are very large and highly degenerate. For such problems simplex type algorithms or interior point methods based on direct factorizations, can only handle small instances. Large instance can be successfully solved with an interior point algorithm that uses a preconditioned conjugate gradient approach to approximately compute interior point directions.

M.R. Emamy-K "How efficient can we maximize threshold pseudo-Boolean functions?" The class of threshold pseudo-boolean functions was introduced by P. L. Hammer et al. about 10 years ago. Existence of a polynomial algorithm to maximize these functions has been an open problem since then.

Pham Dinh Tao (with Le Thi Hoai An) "D.c. (difference of convex functions) Optimization: Theory, Algorithms and Applications." A general discussion of d.c. optimization was presented. Its importance lies in the fact that d.c. programming marks the passage from convex optimization to nonconvex optimization.

Laaura Palagi (with Stefano Lucidi) "Trust region Problems: Theoretic Results and New Algorithmic Developments." The trust region subproblem is important in nonlinear programming as well as other applications in combinatorial optimization. The special structure of the problem allows one to solve an equivalent unconstrained minimization of a piecewise quartic merit function.

Le Thi Hoai An (with Pham Dinh Tao) "An efficient adapted DCA and Branch-and-Bound algorithm for globally solving large-scale 0-1 quadratic programming problems."

A proceedings of the workshop will be published by the American Mathematical Society in the Fields Series.

Workshop on Algebraic Approaches to Quantum Dynamics

7-12 May 1996, The Fields Institute, Toronto
Org.: Niky Kamran (McGill), Peter J. Olver (Univ. of Minnesota), Josef Paldus (Univ. of Waterloo), Mikhail Shifman (Univ. of Minnesota), Alexander Turbiner (UNAM, Mexico)
Sponsors: CRM, Fields Institute and The Theoretical Physics Institute at the Univ. of Minnesota

Since the early days of quantum mechanics, the representation theory of Lie algebras and Lie groups has been successfully employed to compute and analyze the spectra of complicated physical systems which have a great degree of geometrical or dynamical symmetry. Over the past decade, algebraic methods have also started to play a significant role for problems of quantum and statistical mechanics where no such symmetries are present. A simple example which comes to mind is the theory of quasi-exactly solvable systems in quantum mechanics, where the spectral problem associated with the Schrödinger operator may not be exactly solvable, but for which at least part of the spectrum can be computed algebraically owing to the existence of a "hidden" symmetry algebra. Other significant examples of these recent developments include the applications of spectrum generating algebras to molecular dynamics and the role played by quantum algebras in some exactly solvable models in statistical mechanics.

The goal of this workshop was to bring together mathematicians, theoretical physicists and chemists who are actively involved in the development of these new algebraic approaches. There were 29 speakers altogether, whose lectures were organized around three main subthemes:

Quasi-exact solvability and spectrum generating algebras: Alhassid (Yale), Brihaye (Mons), Iachello (Yale), Gonzaalez-Lopez (Madrid), Kamran (McGill), Levine (Hebrew), Lipkin (Weizmann), Matsen (Austin), Milson (Minnesota), Novikov (Steklov/Maryland), Olver (Minnesota), Paldus (Waterloo), Turbiner (UNAM), Ushveridze (Lodz), Wulfman (Pacific), Zaslavskii (Kharkov).

Algebraic methods in statistical mechanics, including quantum groups, the Bethe ansatz and the Yang-Baxter equation: Cizek (Waterloo), Gates (Gainesville), Gould (Brisbane), Kauffmann (Chicago), Kibler (Lyon), Oerhn (Gainesville), Saint-Aubin (CRM), Vinet (CRM), Wiegmann (Chicago).

Other mathematical topics: Gerstenhaber (Penn-

sylvania), Patera (CRM), Rowe (Toronto), Winternitz (CRM).

Because of the somewhat multi-disciplinary nature of the subject, it was of particular concern to the organizers that there be a true dialogue among the mathematicians, physicists and chemists participating in the conference. The expectations of the organizing committee were largely met in this regard. For example, the precise nature of the relationship between the hidden symmetry algebras studied by the mathematicians and the spectrum-generating algebras developed by theoretical physicists and quantum chemists was elucidated during the conference. Likewise, a much better understanding was gained of the elusive problem of quasi-exact solvability in higher-dimensions.

The proceedings of this conference will be published. The organizing committee is presently considering offers from several publishers.

Summer School on Nonlinear Dynamics in Physiology & Medicine

20 May - 7 June 1996, McGill University
Org.: Michael C. Mackey and the Centre for Nonlinear Dynamics in Physiology and Medicine.
Sponsors: CRM, Fields Institute, Department of Physiology of McGill University, Addison-Wesley, Math Works Inc., Springer Verlag

A summer school on Nonlinear Dynamics in Physiology and Medicine ("Montréal 96") was organized and run for the first time by the Montréal based Centre for Nonlinear Dynamics in Physiology and Medicine (CNLD) in the facilities of the Department of Physiology, McGill University. The more than 60 students were selected on a first come, first served basis from over 100 applicants. They came from 16 countries, ranging in subject specialization from biology, medicine, psychology, physiology, and theoretical physics through applied mathematics. Career levels varied from advanced undergraduates through graduate students, postdoctoral fellows, university faculty members and physicians.

Week 1 of Montréal 96 emphasized application of nonlinear dynamics to study the stability of steady states, oscillation, and chaos in biological systems. Week 2 morning lectures dealt with more advanced topics involving bifurcation theory, stochastic models, case studies of situations modelled with inherent delays (hematological disorders), and partial differential equations. The afternoon stream of Week 2 was devoted to time series analysis and the connection with dynamics. The final Week 3 of Montréal 96 was devoted to further case studies that illustrated the use of the techniques developed in the first two weeks in neurological tremor, stochastic resonance in sensory neurons, cardiac re-entry problems, the pupil light reflex, and chaotic behaviour in the periodically stimulated squid giant axon. The close association of all lecturers with the CNLD allowed a tight integration of lecture material and smooth transitions in difficulty of the topics considered. An extensive set of lecture notes written by the lecturers was compiled for each student.

Two features of Montréal 96 were unique. The first was the inclusion and integration of lectures on time series analysis techniques with concepts from dynamics. The second was the daily computer laboratory designed to illustrate the concepts of the lectures through numerical experiments using software written by the lecturers utilizing either the commercially available MATLAB or the freeware XPPAUT (written by Bard Ermentrout, Univ. of Pittsburgh) which incorporates the AUTO bifurcation analysis package written by the CNLD member Eusebius Doedel. Graduate students and postdoctoral fellows of the CNLD served as laboratory assistants, as did the lecturers, to supplement the aid given in the laboratory manual.

Plans are already in progress for a sequel, Montréal 97, and information will be available at the website **`www.cnd.mcgill.ca`**.

CRM Prizes

CRM/Fields Prize 1995

The Centre de recherches mathématiques and the Fields Institute announced in early 1994 the creation of a new prize aiming at recognizing exceptional work in the mathematical sciences. The recipient is chosen by the Advisory Committee of the CRM and the Scientific Advisory Panel of the Fields Institute on the basis of outstanding contributions to the advancement of research. The main selection criterion is research excellence. A prize of $5000 is awarded and the recipient presents a lecture at the CRM and the Fields Institute.

The first CRM/Fields Prize was given last year to **Professor H. S. M. Coxeter** of the University of Toronto. Due to scheduling constraints the award ceremony took place only this fall. On September 22, 1995, Prof. Coxeter gave his lecture "Evolution of Coxeter-Dynkin Diagrams;" afterwards director Luc Vinet presented the award. Prof. Coxeter very kindly accepted to give a second talk, this time for undergraduates. In an overcrowded hall, with people standing along the walls and sitting on the floor, Prof. Coxeter gave a very accessible lecture entitled "Euler's formula for polyhedra." It is an experience that will be remembered by many young mathematicians.

The CRM-Fields Institute Prize for 1995 was awarded to **Professor George A. Elliott** of the University of Toronto and the University of Copenhagen. The awards ceremony took place at the CRM on April 19, 1996, following a lecture by Professor Elliot entitled "C^*-algebras at the CRM." He was cited in particular for his classification of C^*-algebras via invariants related to ordered K-theory. His work has so influenced this field that specialists speak of "the Elliot Program," and he was an invited speaker at the International Congress of Mathematicians in 1994.

George Elliott obtained his B.Sc. and M.Sc. at Queens University in Kingston in 1965 and 1966 and his Ph.D. at the University of Toronto in 1969. After postdoctoral fellowships at the University of British Columbia and Queens University and a year at the Institute for Advanced Study in Princeton, he accepted the position of lektor at the University of Copenhagen in 1972. In 1984 he was named adjunct professor at the University of Toronto.

Professor Elliott has published more than 100 papers and given invited talks at some 48 universities and numerous meetings. He served as editor of the Canadian Journal of Mathematics and the Canadian Mathematical Bulletin and currently edits the Mathematical Reports of the Academy of Sciences of Canada.

In addition to the work cited above George Elliott has made important contributions in other areas of operator algebras: derivations and automorphisms of C^*-algebras, classification of AF-algebras in terms of their ordered K_o-groups, and non-commutative tori.

André-Aisenstadt Prize 1995

Created in 1991, the André Aisenstadt Mathematics Prize is intended to recognize and reward talented young Canadian mathematicians. The Prize, which is given for research achievement in pure and applied mathematics, consists of a $3000 award. The recipient is chosen by CRM Advisory Committee. At the time of nomination, candidates must be Canadian citizens or permanent residents of Canada, and no more than seven years from their Ph.D. Niky Kamran (1991), Ian Putnam (1992), Michael Ward (1994) and Nigel Higson (1994) are the former recipients.

The André Aisenstadt Mathematics Prize for 1995 was awarded to **Professor Adrian S. Lewis** of the University of Waterloo. Professor Lewis was cited for his deep contributions in a wide range of mathematical areas: mathematical optimization, convex and nonsmooth analysis, functional analysis, matrix theory, and computational optimization. In particular he is world renowned for his work in the field of convex programming of Hermitian matrices. The prize was awarded on April 26, 1996 at the CRM by Luc Vinet, director, following a lecture by Professor Lewis entitled "Convex Analysis and Applications."

Professor Lewis did his undergraduate and graduate studies at Cambridge University in England, obtaining his Ph.D. in 1987. His thesis was entitled "Extreme point methods for infinite linear programming." After research fellowships at Cambridge University and Dalhousie University he moved to the University of Waterloo in 1988 where he is currently Associate Professor in the Department of Combinatorics and Optimization.

Adrian Lewis has published more than 30 articles in prestigious refereed journals and has given numerous invited presentations and colloquia, among them a keynote speech at the SIAM Conference on Optimization in 1996. He has also accepted invitations to Marseilles and Toulouse for joint research and expositions of his work. He is a member of the editorial

board of the SIAM Journal on Optimization, and referees and reviews for ten other important journals.

CRM-CAP Prize 1995

The Centre de recherches mathématiques and the Canadian Association of Physicists jointly created this year the CAP/CRM Medal for outstanding achievement in theoretical and mathematical physics. The first Medal was presented at the 1995 CAP Annual Congress to **Professor Werner Israel** of the University of Alberta.

In presenting the Medal to his thesis advisor, mentor, and friend, Dr. Eric Poisson had the following to say regarding Dr. Israel: "Werner was born in Berlin in the early nineteen thirties. Soon after, he and his family moved to Cape Town, South Africa. There he stayed until he moved to Dublin, Ireland, to pursue a graduate degree. Werner obtained his doctorate from Trinity College in 1960. In Dublin, Werner met and married Inge, and the two of them came to live in Edmonton. Werner joined the University of Alberta as an Assistant Professor in 1958, and there he remained to this day.

Werner's field of research is general relativity, most especially black holes. His contributions to this field are numerous and far reaching; throughout his career his role has been that of a leader.

In the late nineteen sixties, Werner formulated a theorem which took everybody working in the field by surprise. Werner showed that nonrotating black holes in isolation must be spherically symmetric, no matter how aspherical the collapsing star initially was. The star could be a cube, and the resulting black hole would still be spherical! This theory created a lot of excitement in the field, and over a period of several years, it was generalized (by Werner as well as other workers) to the case of charged and rotating black holes. This result, now known as the no-hair theorem for black holes, is one of the most powerful and beautiful achievements of gravitation theory.

Most recently, Werner's scientific focus has been on the internal constitution of black holes. His work establishes that the singularity of an aging black hole is lightlike (as opposed to spacelike), and far more ordered than was initially expected.

Werner's work combines deep physical significance with elegant mathematical formulation. Moreover, the vast majority of his work has been original and innovative, which establishes Werner as one of the true leaders in the field of general relativity. In his letter of support for this Prize, Kip S. Thorne writes: 'With two exceptions (Stephen Hawking of Cambridge University and Roger Penrose of Oxford University), nobody has contributed more than Werner Israel to our understanding of gravitational theory, during the past three decades.' "

Seminars

The CRM offers numerous lectures which are part of a regular seminar series. These are generally arranged by local CRM members and take various forms. In some cases there are formal lectures, in others working groups on general subjects are led by researchers.

- **Seminar on "Wavelets"**
  Org.: Jean-Marc Lina (CRM & Univ. de Montréal)

- **Seminar on "History of Mathematics"**
  Org.: Liliane Beaulieu (CRM)

- **Seminar on "Nonlinear Analysis"**
  Org.: Marlène Frigon (Univ. de Montréal)

- **Seminar on "Integrable Systems"**
  Org.: John Harnad (CRM & Concordia Univ.)

- **Seminar on "Mathematical Physics"**
  Org.: Pavel Winternitz (CRM & Univ. de Montréal)

CRM-ISM Colloquium

- **Luc Vinet (CRM), 29 September 1995**
  "Symétries quantiques: introduction aux groupes quantiques"

- **Alessio Corti (University of Chicago), 6 October 1995**
  "Minimal models and the classification of algebraic varieties"

- **Beno Eckmann (E.T.H. Zurich), 13 October 1995**
  "Composition des formes quadratiques et le groupe unitaire infini"

- **Harold Stark (University of California, San Diego), 20 October 1995**
  "Can an L-function be determined by a single value"

- **Nigel Higson (Penn State University), 27 October 1995**
  "C-Algebras and the Topology of Group Representations"*

- **Victor Snaith (McMaster University), 3 November 1995**
  "Some natural occurrences of plus or minus one in number theory"

- **Robert Guénette (Université Laval), 10 November 1995**
  "Fluides rhéologiquement complexes: problèmes théoriques et numériques"

- **Bertram Kostant (M.I.T.), 17 November 1995**
  "Harmonic decompositions and deformed Lie algebra cohomology"

- **Yakov Eliashberg (Stanford University & Harvard University), 24 November 1995**
  "Symplectic geometry and knots"

- **François Soumis (GERAD & École Polytechnique), 1 December 1995**

- **Martin Kruskal (Rutgers University & Princeton University), 8 December 1995**
  "How to tell whether a nonlinear differential equation is integrable"

- **Michel Fortin (Université Laval), 26 January 1996**
  "Méthodes de stabilisation pour les méthodes d'éléments finis mixtes"

- **Ed Bierstone (University of Toronto), 2 February 1996**
  "Resolution of singularities"

- **André Joyal (UQAM), 9 February 1996**
  "Jeux, catégories et communications"

- **Charles Chui (Texas A&M), 16 February 1996**
  "What are wavelets"

- **Mark Goresky (I.A.S.), 23 February 1996**
  "The geometry behind Arthur's trace formula"

- **Barbara Keyfitz (University of Houston), 1 March 1996**
  "Multidimensional conversation laws"

- **Jérôme Detemple (CIRANO & McGill University), 8 March 1996**
  "American Options and Stochastic Volatility"

- **Hector Sussmann (Rutgers University), 22 March 1996**
  "Geometry and nonlinear control, 300 years after Johann Bernoulli's brachistochrone"

- **Paul Deheuvels (Université de Paris), 29 March 1996**
  "Fractals Aléatoires"

- **Michael Thaddeus (Harvard University), 12 April 1996**
  "Complete Quadrics and Punctured Curves"

- **Catherine Sulem (University of Toronto), 3 May 1996**
  "Phénomène d'autofocalisation pour les équations de Schrödinger nonlinéaires"

Theme Year 1996-1997: Combinatorics and Group Theory

Overview

The theme year 1996-1997 is devoted to combinatorics and group theory. Besides the CRM Summer School at Banff and the Chaire Aisenstadt, there will be eight workshops and conferences. The members of the scientific committee for this year are: G. Baumslag (CUNY), F. Bergeron (UQAM), N. Bergeron (York), G. Brassard (Montréal), C.J. Colbourn (Waterloo), C. Crépeau (Montréal), R. Couture (Montréal), P. Flajolet (INRIA, Rocquencourt), A. Garsia (UCSD), S.M. Gersten (Utah), E. Ghys (Lyon), D. Gildenhuys (McGill), G. Hahn (Montréal), O. Kharlampovich (McGill), D. Krob (Paris VI), G. Labelle (UQAM), C. Lam (Concordia), P. L'Écuyer (Montréal), P. Leroux (UQAM), R.C. Mullin (Waterloo), H. Niederreiter (Austrian Academy of Sciences), C. Reutenauer (UQAM), A. Rosa (McMaster), G. Sabidussi (Montréal), R.P. Stanley (M.I.T.), D.R. Stinson (Nebraska-Lincoln), L. Vinet (Montréal), D. Zeilberger (Philadelphia), E. Zelmanov (Yale).

The scientific events are described below. They will take place at the CRM unless specified otherwise.

Workshop on Pseudorandom Number Generation

3-28 June 1996

Org.: G. Brassard (Montréal), C. Crépeau (Montréal), R. Couture (Montréal), P. L'Écuyer (Montréal), H. Niederreiter (Austrian Academy of Sciences)

The main goal of this workshop is to bring together researchers interested in theoretical and practical aspects of (pseudo-)random number generation by computer. The workshop is spread over a period of 4 weeks. The general theme is the development of practical random number generation software for different classes of applications, such as simulation, statistics, numerical analysis, games, cryptography, etc. The main subjects to be discussed are linear-type methods, nonlinear methods, statistical tests, cryptographically secure generators, parallel generators and efficient software implementations. Within the general theme, each week will have a special subject interest, as follows: (i) requirements for good generators, randomness criteria and statistical tests in general (June 3-7), (ii) linear methods (June 10-14), (iii) nonlinear methods and cryptographically secure generators (June 17-21), (iv) parallel generators and practical software implementations (June 24-28).

The list of invited speakers includes: A. Compagner, R. Couture, C. Crépeau, E.C. Dudewicz, G. Fishman, M. Fushimi, P. Hellekalek, F. James, G. Larcher, P. L'Écuyer, G. Marsaglia, M. Mascagni, M. Matsumoto, H. Niederreiter, I.M. Sobol', S. Tezuka, I. Vattulainen.

CRM Summer School on Group Theory

Banff Centre of Arts, Banff, Alberta

11-23 August 1996

Org.: G. Baumschlag (CUNY), D. Gildenhuys (McGill), O. Kharlampovich (McGill), E. Zelmanov (Yale)

The summer school will be aimed primarily at Ph.D. students in their final years and recent Ph.D.'s. Its main objective will be to prepare people for the workshops to follow. The topics will be: combinatorial and geometric group theory, hyperbolic and automatic groups, actions of groups on trees, connections between groups and Lie algebras, pro-p-groups, group representations (aimed particularly at the combinatorialists).

The list of invited lecturers includes: G. Baumslag, I. Chiswell, M. du Sautoy, S. Gersten, N. Gupta, K. Gupta, S. Ivanov, O, Kharlampovich, Yu. Kuz'min, A. Myasnikov, M. Sapir, E. Zelmanov.

Workshop on Cayley Graphs

16-21 September 1996

Org.: G. Hahn (Montréal), G. Sabidussi (Montréal)

Cayley graphs of finite and infinite groups will be explored from the point of view of the central role which they play in the general theory of transitive graphs, as well as for the applications which have been found in recent years in the design of interconnecting networks. Specific topics will include combinatorial properties related to the communication of information in Cayley graphs, isomorphism and homomorphism problems, graphs with groups of polynomial growth.

The list of invited speakers includes: N. Alon, B. Alspach, L. Babai, P. Cameron, M.J. Dunwoody, Y. Hamidoune, W. Imrich, S. Klavzar, A. Lubotzky, D. Marusic, B. Mohar, N. Seifter, J. Sirán, V. Trofimov, M.E. Watkins, W. Woess.

Workshop on Hyperbolic and Automatic Groups; Groups Acting on R—Trees

13-24 October 1996

Org.: G. Baumschlag (CUNY), D. Gildenhuys (McGill), O. Kharlampovich (McGill), E. Zelmanov (Yale)

This workshop will bring together international experts in the indicated fields.

The list of invited speakers includes: M. Bestvina, S. Gersten, I. Kapovich, G. Levitt, A. Olshanskii, E. Rips, Z. Sela, H. Short, M. Staretz.

Workshop on Distance-Regular Graphs

18-23 November 1996

Org.: G. Hahn (Montréal), G. Sabidussi (Montréal)

The workshop is intended to cover recent developments in all aspects of the theory of distance-regular graphs. One of the major themes will be distance-transitive graphs and problems concerning their classification and connections with group theory.

The list of invited speakers includes: E. Bannai, N. Biggs, A.E. Brouwer, P. Cameron, A. Cohen, A.D. Gardiner, C. Godsil, A.A. Ivanov, L.K. Jørgensen, M. Mulder, J. Saxl, P. Terwilliger.

Workshop on General Combinatorial Group Theory

5-16 April 1997

Org.: G. Baumschlag (CUNY), D. Gildenhuys (McGill), O. Kharlampovich (McGill), E. Zelmanov (Yale)

This workshop will include a wide variety of topics in Combinatorial Group Theory, in particular, invariants of infinite groups, profinite groups and constructive aspects of pro-p-groups, exponential groups, language theory, connections between groups and Lie algebras, group actions on non-archimedean trees.

The list of invited lecturers includes: H. Bass, G. Baumslag, R. Grigorchuk, M. Gromov, A. Krasilnikov, G. Labute, A. Lubotzky, J. McCool, A. Myasnikov, Remeslennikov, L. Ribes, A. Shmelkin.

Workshop on Tranversal Designs and Orthogonal Arrays

University of Waterloo, Waterloo, Ontario, April 1997

Org.: C.J. Colbourn (Waterloo), R.C. Mulin (Waterloo), A. Rosa (McMaster), D.R. Stinson (Nebraska-Lincoln)

As combinatorial design theory has matured, certain central objects have been found to play a key role not only in the construction of designs, but also in their application. Transversal designs (equivalently, orthogonal arrays) occupy a fundamental place in the construction of almost all types of designs, primarily as a result of Wilson's existence theory for designs. A central question in combinatorial design theory is therefore the existence of transversal designs. A one week workshop on the subject is planned for April 1997 and the following five main themes will be covered: finite geometry and difference sets, orthogonal arrays in coding theory, incomplete transversal designs, orthogonal arrays and experimental design, applications of transversal designs in design theory.

The list of speakers includes: J. Abel, F. Bennett, J. Bierbrauer, A. Brouwer, A. Bruen, J. Dinitz, J. Doyen, S. Hedayat, K. Heinrich, D. Jungnickel, D. Kreher, C. Laywinve, G. Mullen, N. Sloane, D. Street, V. Tonchev, J. van Rees, R. Wilson, M. Wojtas, L. Zhu.

Workshop on Experimental Mathematics and Combinatorics

19-30 May 1997

Org.: F. Bergeron (UQAM), G. Labelle (UQAM), P. Leroux (UQAM)

Computer algebra methods play an increasingly important role in mathematics. This is particularly true in areas like combinatorics where mathematical experiment is an integral part of any research activity. The goal of this workshop is to survey recent developments in computer algebra as a research tool in mathematics and to work on specific applications primarily in combinatorics. The workshop will consist of one week of invited talks (May 19-23, 1997) followed by one week of informal working sessions.

The list of invited speakers includes: J. Borwein, P. Borwein, P. Flajolet, T. Guttmann, B. Salvy, D. Stanton, V. Strehl, G.X. Viennot, D. Zeilberger, M. Petkovsek

Workshop on Algebraic Combinatorics

9-20 June 1997
Org.: FBergeron (UQAM), N. Bergeron (York), C. Reutenauer (UQAM)

The purpose of the workshop is to study interactions between Algebraic Combinatorics and Symmetric Functions, with special emphasis on Descent Algebras of Coxeter groups in relation to quasi-symmetric functions and non-commutative symmetric functions, and on doubly parametrized (Macdonald) (q,t)-symmetric functions, in relation to harmonics of reflection groups.

The list of speakers includes: P. Diaconis*, A. Garsia, I. Gessel, I. Goulden*, M. Haiman, I.G. Macdonald, C. Procesi, L. Solomon, R.P. Stanley, J.Y. Thibon. (The asterisk * indicates a speaker yet to be confirmed.)

Chaire Aisenstadt

Professor László Babai will be giving the first part of the André-Aisenstadt Lectures at the CRM in conjunction with the workshops on Cayley Graphs and on Distance-Regular Graphs in September and November 1996. Fields Medal (1994) winner Professor Efim Zelmanov will hold the second part of the Chaire Aisenstadt, and will be delivering a series of lectures on Combinatorial Algebra in March 1997.

Theme Year 1997-1998: Statistics

Overview

The theme year in statistics will emphasize several current directions in the theory and application of statistics, with particular emphasis on problems involving dependent data. Five areas of concentration have been selected: the interface between computation and theoretical statistics, spatial statistics, nonparametric functional estimation, statistical methods in epidemiology and genetic epidemiology, and analysis of longitudinal data.

The members of the advisory committee for the theme year are J.F. Lawless (Waterloo), M. Moore (École Polytechnique), N. Reid (Toronto) and Y. Yatracos (U. de Montréal). The organizers for the concentration programs have been encouraged to emphasize, as much as is feasible, interaction with researchers having special expertise in applications.

Spatial statistics and applications

A great many application areas, such as geology, hydrology, medical imaging, atmospheric science, biology, materials science, and so on, routinely collect large amounts of data that exhibit spatial dependence. Spatial data also raises many interesting inferential problems and statistical methods developed for independent data are rarely applicable. This program plans to explore recently developed methods for particular applications, as well as more general problems of inference.

The program as planned consists of a short course of 20-30 hours to be given over a period of about 3 weeks, to introduce students and others to the general problems and methods of spatial data analysis. This will be followed by four workshops on the topics indicated below.

Image analysis and image restoration

30 March - 3 April 1998
Org.: M. Moore (École Polytechnique)

Statistical inference for spatial processes

6-9 April 1998
Org.: Xavier Guyon (Univ. Paris 1)

Applications in earth and environmental sciences

20-24 April 1998 (tentative)
Org.: R. Lockhart (Simon Fraser)

Statistics of brain mapping
13-14 June 1998
Org.: K. Worsley (McGill)

Functional magnetic resonance imaging is a new and rapidly developing area of medical imaging technology, and there is international expertise in this topic in Montreal. This workshop will follow the 4th International Conference on Functional Mapping of the Human Brain (7-12 June 1998).

Nonparametric functional estimation

Nonparametric functional estimation is widely used in theory and applications, with emphasis usually being on the estimation of density functions, distribution functions, quantile functions, regression functions and nonlinear functionals of the density. Most results to date have been obtained in the framework of independent sampling, but current research directions motivated by applications consider nonparametric functional estimation under various types of dependence.

Nonparametric functional estimation
13-24 October 1997
Org.: Luc Devroye (McGill), George Roussas (U.C. Davis), Yannis Yatracos (Univ. de Montréal)

Statistical methods in epidemiology and genetic epidemiology

Much work in epidemiology is descriptive, but there is considerable recent interest in emphasizing techniques of statistical inference in epidemiology. This program will invite several internationally known researchers to discuss various aspects of statistical methods in epidemiology. The program will consist of a two-week conference, with emphasis in the first week on epidemiology and in the second week on genetic epidemiology. Each topic will have two or three themes with an associated substantive researcher responsible for background lectures.

Statistics and epidemiology
3-9 May 1998
Org.: Gerarda Darlington (Toronto), Shelley Bull (Toronto)

Recent developments in descriptive epidemiology, etiologic studies, and clinical epidemiology.

Genetic epidemiology
9-16 May 1998
Org.: Gerarda Darlington (Toronto), Ken Morgan (McGill)

A discussion of statistical and genetic principles (segregation analysis, linkage analysis, association analysis, population genetics, isolate populations, linkage disequilibrium mapping); complex pedigrees and complex traits (gene identity by descent - families, gene identity by descent - individuals).

Longitudinal data analysis

Data collected on the same subjects over time arise frequently in biological applications, and there is a considerable new body of work on models and methods for this type of data. This workshop will provide a survey of recent work, and a discussion of open problems in the area. The emphasis will be on applications, and participants are encouraged to bring particular applied problems to the attention of the workshop organizers.

Longitudinal data analysis for complex surveys
March 1998 (tentative)
Org.: Michael Hidiroglou, Sylvie Michaud and David Binder (Statistics Canada)

Nonlinear time series
March 1998 (tentative)
Org.: Roch Roy (Univ. Montréal)

Time series analysis continues to be a subject of important interest in statistics since almost every scientific discipline is concerned with data collected over time. This workshop will focus mainly on two topics of recent and growing interest: resampling methods and the application of wavelets. In many cases, the related results are applicable to both linear and non linear time series.

Event history analysis
25-29 May 1998
Org.: Richard Cook and Jerry Lawless (Waterloo)

Event history analysis is now commonly applied in most branches of science, including demography, epidemiology, medicine, engineering and economics. The purpose of this workshop is to stimulate a critical appraisal of existing models and techniques and to consider future developments.

Theoretical statistics and computation: the interface

Advances in computing power are not only influencing the practice of statistics, but are also influencing the development of theoretical statistics. Computationally intensive techniques such as the bootstrap and Monte Carlo Markov Chain (MCMC) algorithms provide alternatives to inferential approximations developed using asymptotic theory. The application of MCMC techniques to Bayesian analysis of relatively complex problems has provided new impetus for development of standard priors. The wide availability of symbolic computation has also influenced the types of inference problems that can be tackled.

This program will consist of three periods of concentration, each of approximately two weeks, in the areas given below. The format for each period of concentration will consist of a week of background lectures for students and participants, followed by a week long research workshop.

USING THE BOOTSTRAP FOR MODEL SELECTION
14-20 September 1997
Org.: Christian Léger (Univ. de Montréal)

SYMBOLIC COMPUTATION
21-27 September 1997
Org.: James Stafford (Western Ontario)

EMPIRICAL BAYES AND LIKELIHOOD INFERENCE
9-15 November 1997
Org.: Ejaz Ahmed (Regina), Nancy Reid (Toronto)

CRM Summer School on Likelihood and Asymptotics

1-11 August 1997, Banff
Org.: Tom DiCiccio (Cornell)

Aisenstadt Lectures

Professor Peter Hall of the Australian National University in Canberra and Sir David Cox of Oxford University have accepted invitations to serve as Aisenstadt Lecturers in October 1997 and May 1998 respectively.

Interaction with the Fields Institute

John Chadam has expressed enthusiastic support for having the Fields Institute sponsor activities in statistics and is happy to tie that in with the theme year if that seems appropriate. He has also been independently in contact with Jack Kalbfleisch at Waterloo to discuss a program in Industrial Statistics at the Fields Institute and is willing to work that into the theme year.

Updated information about the schedule and speakers may be obtained from Nancy Reids' web page

`www.utstat.toronto.edu/reid/crm/`.

Theme Year 1998-1999: Number Theory

Overview

The year 98-99 will be devoted to number theory. The organizing committee is M. Ram Murty (McGill and Queen's, scientific director), Henri Darmon (McGill)), Mark Goresky (Institute for Advanced Study), Fiona Murnaghan (Toronto), V. Kumar Murty (Toronto). The focus will be on the four following areas of number theory.

(i) Algebraic cycles and Shimura varieties
(ii) Elliptic curves and automorphic forms
(iii) p-adic representations
(iv) Analytic theory of automorphic L-functions

Each of these areas will be studied by means of a seminar course given by members of the organizing committee. This seminar course will be aimed primarily at graduate students and postdoctoral fellows. The course will be supplemented by a one-week workshop where specialists will lecture on the latest developments. Most likely, the topics *(i)* and *(ii)* will be treated by K. Murty, H. Darmon, and M. Goresky in the first term. Topics *(iii)* and *(iv)* will be covered by F. Murnaghan and R. Murty respectively in the second term. In one or more of these areas, it is proposed to have some lecture notes published in the CRM series.

In addition, there will be a summer school in Banff, Alberta on Algebraic Cycles, June 7-19, 1998, organized by J. Lewis (Alberta), N. Yui (Queens's) and B. Gordon (Oklahoma). The following have so far agreed to speak at the summer school: S. Bloch (Chicago), J.-L. Colliot-Thélène (CNRS), M. Green (UCLA), U. Jannsen (Cologne), B. Lawson (SUNY), D. Ramakrishnan (Caltech), S. Saito (Tokyo), D. Zagier (Max Planck Institut). Several other speakers have been invited.

COLLABORATION WITH THE FIELDS INSTITUTE

This year the CRM and the Fields Institute have again enjoyed a very high level of collaboration.

First of all, the CRM and the Fields Institute have jointly invested much effort in the development of the PIms/NNCMS initiative. This has required numerous meetings across the country among the directors of both institutes and other parties. These have allowed the two directors to coordinate efficiently the scientific activities of the institutes and to develop new joint projects. It should also be mentioned that Robert Moody is a member of both the CRM's advisory committee and the Fields Institute's scientific committee and he thus facilitates communication between these two committees.

The CRM and the Fields Institute have jointly sponsored many events. For instance the CAMS meeting at Memorial University, the workshop on Partial Differential Equations and their Applications held at the Fields Institute, the meeting on Nonlinear Dynamics and Time Series that took place at the CRM, the one on Semidefinite Programming & Interior-Point Approaches for Combinatorial Optimization Problems held at the Fields Institute and the workshop on Algebraic Approaches to Quantum Dynamics at the Fields Institute.

A number of CRM's members have taken part in the organization of scientific activities at the Fields Institute. J. Patera (together with R. Moody) has been responsible for organizing a theme-semester on the mathematical foundations of periodic order in the fall of 1995. J. Hurtubise was on the scientific committee of the workshop on Interaction between Topology and Physics that took place in April in the framework of theme activities in Homotopy Theory. Niky Kamran coorganized the meeting on Algebraic Approaches to Quantum Dynamics that was co-sponsored by CRM.

The CRM and the Fields Institute have jointly supported a postdoctoral fellow, Sadok Kallel, who was in residence at the Fields Institute during the program in Homotopy Theory.

Plans are also being made to hold at the Fields Institute parts of the CRM 1997 theme activities in Statistics and of the 1998 program in Number Theory and Algebraic Geometry.

Finally the year has also seen the awarding of the second CRM/Fields Institute prize to George Elliott in recognition of outstanding contributions to the mathematical sciences.

PARTNERSHIPS

The research group PHYSNUM, led by B. Goulard, joined the CRM during the year 95-96. This event was particularly important for the development of research in applied and industrial mathematics. The PHYSNUM group is presently involved in mathematical imaging and risk management. These activities have emerged from more general research programs based on wavelet theory, neural networks and parallel computing. Beside theoretical work on wavelets (now recognized internationally), the PHYSNUM team has acquired expertise in various aspects of image processing. Recent projects include analysis of images (from satellites and of digital mammograms) based on multiscaling representations given by wavelet transforms. PHYSNUM is pursuing a number of project in collaboration with industry. It enjoys a unique partnership with Atlantic Nuclear Services initiated five years ago. It also has ties with the Hôpital Notre-Dame de Montréal, Noranda (Montréal), and the Canadian Centre for Remote Sensing (Ottawa). The group leader, Bernard Goulard, has received an honourable mention from the NSERC University-Industry Synergy 1995 program for establishing successful partnerships. The group also offers industrial fellowships to young scientists with Ph.D.'s in fundamental domains. So far all the fellows of this group have found positions in industry (ANS, CAE, Hydro-Québec, Lockheed Martin Electronic Systems Canada) at or before the end of their stipend.

Over the last three years, the CRM has enjoyed a close collaboration with two liaison and research transfer centres, the CERCA (*Centre de recherche en calcul appliqué*) and the CIRANO (*Centre interuniversitaire de recherche en analyse des organisations*), and two centres involved in applied and contractual research, the CRT (*Centre de recherche sur les transports*) and the GERAD (*Groupe d'etudes et de recherche en analyse des décisions*). Their interests are in applied numerical computations (CERCA), in management, economy, and finance (CIRANO), in problems related to transportation (CRT) and in risk and decision (GERAD). The collaboration with these partners takes various forms. In particular, it has allowed the CRM to set up an industrial postdoctoral fellowship program and to hold meetings that were jointly organized.

Industrial postdoctoral fellowship program. This program was established three years ago to support research in industrial mathematics, contribute to the training of specialists in this area and foster collaborations between the university and industry. Four fellowships, jointly funded by the CRM and industry, were awarded in 1995-96. The CRM's partners in this program include Ad Opt and Cognologic for one postdoctoral fellow (pdf) dealing with monthly scheduling of airline flight personnel, Environment Canada for one pdf dealing with regional-atmosphere modelling, Bombardier Canada, Pratt & Whitney and Environment Canada for one dealing with wing icing during flights, and Bombardier Canada, GE Canada, Hydro-Québec, and Environment Canada for one dealing with large-scale turbulence.

University-industry workshops. The first semester of the current thematic year was devoted to computational hydrodynamics and was organized jointly with CERCA. It included one large conference and two workshops, one with several mini-courses. It welcomed scientists from both industry and academia. A week-long meeting on the mathematics of finance was held in April 96, funded by both the CIRANO and the CRM, with support from AMI Partners Inc., the Bourse de Montréal, the Caisse de dépôt et placement du Québec, and Hydro-Québec. The audience was made up of economists, bankers and mathematicians.

The industrial associate member (E. Shahbazian) and three visiting members of the CRM (L. Gagnon, M. Mayrand and P. Valin) are scientists working for Lockheed Martin Electronic Systems. Two Ph.D. students are co-supervised by J. Patera (Univ. de Montréal), L. Gagnon and E. Shahbazian, with part of their thesis work being done at Lockheed Martin.

The centres CERCA, CIRANO, CRM, CRT and GERAD are currently writing a grant proposal to be submitted to NSERC in its new research network program. If awarded, this grant would allow the CRM to sustain and expand its research efforts in applied and industrial mathematics.

AWARDS, DISTINCTIONS & LANDMARKS

Michel Delfour wins ACFAS Prix Urgel–Archambault

Michel Delfour, regular member at CRM and professor in the Département de mathématiques et de statistique at the Université de Montréal, was awarded in 1995 the Prix Urgel-Archambault by the Association canadienne-française pour l'avancement des sciences (ACFAS). This prize was created in 1953 in memory of Urgel Archambault, director and founder of the École Polytechnique de Montréal. It rewards scientists working in the physical sciences, mathematics and engineering. It is sponsored by Alcan.

The ACFAS citation is as follows: "Michel Delfour's career has deeply marked mathematical life in Quebec and Canada. Born in Paris, he moved to Montréal and studied electrical engineering at McGill University where he won several awards. He chose to specialize in mathematics and obtained a Ph.D. from the Case Western University in Cleveland. Coming back to Canada, he was successively invited researcher at the Université de Montréal, member of the Centre de recherches mathématiques, and professor in the Département de mathématiques et de statistique at this institution.

"Michel Delfour is a brilliant scientist, original and with extremely diversified gifts. His research, concentrated in applied mathematics, has at least five parts. The first two, developed in the context of the Canadian space program, deal with control and stabilization of systems as well as shape and structure optimization. The applications of this work are numerous, ranging from flexible structure modelling to satellite design.

"Michel Delfour has also worked on the modelling and control of systems with delay, on discontinuous approximation methods for ordinary differential equations and on wavelength assignment, a problem with obvious financial consequences. The results of his last project were extremely well received by the federal Ministry of Communications.

"Besides his accomplishments as a researcher, Michel Delfour has two remarkable qualities as a mathematician: conciseness and elegance. His fifty (or so) articles are models of clarity and mathematical taste. He is an exception to the rule that mathematicians prefer to work alone; all his colleagues praise his team spirit and his enthusiasm is contagious.

"Michel Delfour is currently finishing his third monograph. His international reputation is significant, as his invitation to be a plenary speaker at a SIAM conference indicates. (SIAM is the most prestigious society of applied mathematics in the world.) He won a Killam fellowship in 1989-1991 and is the president since 1991 of the Canadian Mathematical Society."

(The mandate of Prof. Delfour as President of the Canadian Mathematical Society ended in 1994.)

Professor Robert P. Langlands shares Wolf Prize

In November 1995, the Wolf Foundation of Israel announced the award of the Wolf Prize jointly to two mathematicians. Robert Langlands and Andrew Wiles (Princeton University) shared the $100,000 prize in mathematics for their ground-breaking research in number theory and related areas. The award was presented to them in Jerusalem in March by Ezer Weizman, President of Israel.

Prof. Robert P. Langlands, 59, did his undergraduate work at the University of British Columbia and his Ph.D. at Yale University. He was subsequently instructor and assistant professor at Princeton University and professor at Yale. Since 1972, he is a member of the Faculty of the Institute for Advanced Study's School of Mathematics (Princeton). According to the Wolf Foundation's citation, Langlands received the Wolf Prize for his "path-blazing work and extraordinary insights in the fields of number theory, automorphic forms, and group representation." His foundational work on Eisenstein series, group representations, *L*-functions and the Artin conjectures, the principle of functoriality, and the formulation of the far-reaching Langlands program shaped the modern theory of automorphic forms and influenced much subsequent research.

Prof. Langlands has been a regular member of the CRM for the past few years. He spends a part of each summer at the CRM. He initiated the CRM summer school, first held in 1990, and has organized a workshop on "Zeta Functions of Picard Modular Surfaces" (spring 88) that still yields scientific results. He has also codirected several students with Y. Saint-Aubin.

Professor Carolyne Van Vliet retires

Professor Carolyne Van Vliet has retired in 1995 after more than 25 years at the Centre de recherches mathématiques and at the Département de physique at the Université de Montréal.

Prof. Van Vliet obtained her Ph.D. from the Free University of Amsterdam in 1956. From 1956 to 1970, she was first postdoctoral fellow and subsequently professor of electrical engineering at the University of Minnesota. She was one of the first researchers to be hired at the Centre de recherches mathématiques in 1969. Her interests, since the beginning of her career, lie in mathematical, statistical and solid state physics, more specifically in out-of-equilibrium statistical mechanics (in particular linear response theory and the description of *N*-body correlation and relaxation processes), quantum transport in condensed matter, fluctuations and stochastic processes, and mesoscopic phenomena in quantum mechanics and electrodynamics.

Following some severe but valid criticism of Kubo's linear response theory, made for example by N. van Kampen, Prof. Van Vliet started, in 1978, a profound revision of this theory consistent with fundamental principles of statistical mechanics such as entropy production and irreversibility in transport processes. She derived, using Zwanzig's projection operator technique and within the famous Van Hove limit, a generalized master equation, with external fields present and thus more general than that of Pauli or van Hove, general many-body linear response formulas for the conductivity, and two quantum Boltzmann equations. Her series of four articles *Linear Response Theory Revisited I-IV*, published between 1978 and 1984 in the Journal of Mathematical Physics, constitutes a remarkable contribution to the field. This mathematical theory has been applied to magnetotransport and hopping conduction in disordered materials. Her graduate students also gave other important applications.

Another of her important results is related to the long-standing controversy over Handel's quantum theory of the *1/f* noise. Prof. Van Vliet resolved this debate by giving a rigorous treatment based on quantum electrodynamics. A further extension of the theory, involving the very pertinent electron-phonon interaction, was recently completed by one of her students.

Prof. Van Vliet is extremely prolific, with some 200 articles, and is still very active: she pursues her teaching and research career at Florida International University (Miami) while still maintaining her ties to the CRM.

A team from CRM and UQAM receives an NSERC Collaborative Grant

NSERC established the highly competitive Collaborative Grant Program to foster and support multidisciplinary research programs. A grant was awarded during the fall of 1995 for a proposal entitled *Algebraic Combinatorics and Quantum Integrable Models*. The team consists of: L. Vinet (CRM, team leader), F. Bergeron (UQAM), N. Bergeron (York), R. Floreanini (INFN, Trieste), A. Garsia (UC at San Diego), J. Harnad (Concordia), D. Levi (Univ. di Roma III), C. Reutenauer (UQAM), Y. Saint-Aubin (CRM), Pavel Winternitz (CRM).

The project lies at the interface of theoretical physics and combinatorics, and focuses on integrable systems and special function theory. Integrable systems are very important in physics since they often allow us to find fundamental laws. A paradigm is the Calogero-Sutherland (CS) model which describes *N* particles on a circle with long-range interactions. It is known to be relevant to the physics of the fractional quantum Hall effect and of high-T_c superconductivity. It was found recently that the wave functions of the CS model can be expressed in terms of the multivariate Jack polynomials. The CS model also admits a relativistic generalization; in this case the quantum dynamics are governed by a q-difference equation whose solutions are expressed in terms of Macdonald symmetric polynomials.

The Jack and the Macdonald polynomials are some of the principal objects of study in algebraic combinatorics. Many important and challenging conjectures about these polynomials are still unproved. Very recently, a representation-theoretical setting for the Macdonald basis was discovered by members of the team. This construction led them to discover remarkable properties of these polynomials by skilfully using techniques of algebraic geometry, algebraic combinatorics and computer algebra. Drawing from physical intuition, other members of the team have obtained an operator solution of the CS model that sheds new light on many outstanding physical and mathematical problems.

The main objective of the program is to study the various algebraic and combinatorial aspects of the CS model and its generalizations. This will most likely lead to significant advances in many important mathematical and physical areas (condensed matter physics, special function theory, conformal field theory, representation theory, algebra, integrable systems, etc.) that this model connects in an extraordinary way.

Research done at CRM is one of the 10 Québec Science discoveries of the year

Each year the popular science monthly *Québec Science* presents a group of 10 discoveries done during the last twelve months in the Province of Québec. The selection criteria are numerous: among them are the impact on the field of research, publication in prestigious journals and the improvement of human welfare. The issue of February 1996 contained this year's winners. A recent work of Luc Vinet, director of the CRM, and Luc Lapointe, his Ph.D. student (Département de physique at the Université de Montréal) was cited as one of the 10 discoveries for 1995.

This recognition came for their proof of a famous conjecture by Macdonald on a class of symmetric functions known as the Jack polynomials. These functions, as was mentioned before, play, on the one hand, a key role in algebraic combinatorics — they are deformations of the Schur functions and appear, on the other hand, in the expression of the Calogero Sutherland (CS) model wave functions.

The Macdonald conjecture that Lapointe and Vinet proved can be presented roughly like this. The Jack polynomial depend on one parameter (the coupling constant of the CS model). These functions are usually presented through their expansion on another set of symmetric functions known as the symmetric monomials. The Macdonald conjecture asserted essentially that the expansion coefficients are themselves polynomials in the parameter. This conjecture has resisted for more than seven years the efforts made to prove it.

The proof that Lapointe and Vinet gave makes use of the methods of mathematical physics. They found the creation operators of the CS model whose action on the ground state wave function generates the wave functions of the excited states. They have thus discovered a remarkable formula for the Jack polynomials from which the Macdonald conjecture followed as a simple corollary.

COMPUTER FACILITIES

The CRM offers to its members and visitors a Unix environment based on a SUN Sparc 1000 equipped with eight 100-Mhz processors and 256 Mb of memory. This computing power is distributed through the offices and common rooms via Sun stations (Sparc 4, 5 and 10) and X-terminals. The software libraries include compilers (several C and C++, Fortran, etc.), symbolic manipulation programs (Mathematica, Maple and Macaulay), several text editors, web browsers, mail tools, and most utilities common to the mathematical world. Upgrades to TeX and its dialects are uploaded whenever they are released.

The local net is linked to the network of the Université de Montréal that maintains the connections with RISQ (Réseau interordinateurs scientifique québécois) and CA*net (the Canadian internet transit service).

The CRM also has a Silicon Graphics Challenge L with six R4400 processors at 100 Mhz and 128 Mb of memory that was purchased through the NSERC grant of one of its research teams. Access to this server is limited to the members of the team or, upon request, to other members with numerical processing needs.

The support staff works on Sun stations, on X-terminals or on Macintoshes tied to the Sun server for mail services and back-ups.

This year the CRM, the Fields Institute and the PIms submitted a joint grant application to NSERC's Major Facilities Access program. The proposal calls for the establishment of a National Computer Network for Mathematical Research. This network would help maintain and enhance the computing facilities offered at the three institutes, and would allow for the development of better electronic connectivity in the mathematics community. Though the three-year grant was not awarded, NSERC recognized the value of the project by giving $ 75K as seed money for the network.

PUBLICATIONS

Books

The CRM publishes monographs, lecture notes, proceedings, software, videos, and research reports. (For the latter see below.) It has several collections. The in-house collection Les Publications CRM offers many titles in both English and French. The CRM also has publishing agreements with both the American Mathematical Society (AMS) and Springer-Verlag. Two collections, edited by CRM, are published and distributed by the AMS. They are the CRM Monographs and the CRM Proceedings and Lecture Notes. The latter collection will contain the new English translation of D. Knuth's monograph "Mariages stables et leurs relations avec d'autres problèmes combinatoires" (originally published in French in the CRM's own collection). Springer-Verlag publishes the CRM Series in Mathematical Physics. The following list contains books that have appeared during the year 95-96 or that will be published soon.

Les Publications CRM

- P. Koosis, *Leçons sur le théorème de Beurling et Malliavin*, fall 1996.
- D. W. Rand, *Concorder, Concordance Software for the Macintosh, Version Three*, Software and Manual, fall 1996.
- X. Fernique, *Fonctions aléatoires gaussiennes, vecteurs aléatoires gaussiens*, to be published in spring 1997.

AMS CRM Monographs

- J. Milton, *Dynamics of Small Neural Populations*, vol. 7, 1996.
- I. Karatzas, *Lectures on the Mathematics of Finance*, Chaire Aisenstadt 1996-1997, vol. 8, to be published in October 1996.
- R. Bryant, *The Geometry of Differential Equations*, Chaire Aisenstadt 1995-1996, to be published in spring 1997.

AMS CRM Proceedings & Lecture Notes

- J. Feldman, R. Froese and L. Rosen (ed.), *Mathematical Quantum Theory: Schrödinger Operators*, CRM Proc. & Lecture Notes, vol. 8, 1995.
- D. Levi, L. Vinet and P. Winternitz (ed.), *Symmetries and Integrability of Difference Equations*, vol. 9, September 1996.
- D.E. Knuth, *Stable Marriage and its Relation to Other Combinatorial Problems*, vol. 10, October 1996.
- L. Vinet (ed.), *Advances in the Mathematical Sciences — CRM's 25 Years*, vol. 11, to be published in spring 1997.
- P. Greiner, V. Ivrii, L. Seco, C. Sulem (eds.), *Partial differential equations*, June 1995, to be published in spring 1997.

Springer-Verlag CRM Series in Mathematical Physics

- G. Semenoff and L. Vinet (eds.), *Particles and Fields, CRM Banff Summer School 1994*, to be published in December 96.
- L. Vinet (ed.), *Theoretical and Mathematical Physics, Proceedings of the Canadian Association of Physicists Meeting 1995*, to be published in spring 1997.

Research Reports

[CRM-2290] V. Hussin and G. Rideau. *Quantum fermionic oscillator group from R-matrix method*, June 1995.

[CRM-2291] O. Hijazi. *Twistor operators and eigenvalues of the Dirac operator*, June 1995.

[CRM-2292] A. F. Ivanov and J. Losson. *Stable rapidly oscillating solutions in delay equations with negative feedback*, June 1995.

[CRM-2293] K. Ohshika. *A convergence theorem for Kleinian groups which are free groups*, July 1995.

[CRM-2294] L. Lapointe and L. Vinet. *A Rodrigues formula for the Jack polynomials and the Macdonald-Stanley conjectures*, July 1995.

[CRM-2295] P. W. Doyle and A. M. Grundland. *Invariant solutions of quasilinear systems of partial differential equations*, July 1995.

[CRM-2296] Y. Berest. *Invariant solutions of quasilinear systems of partial differential equations*, July 1995.

[CRM-2297] V. Spiridonov and A. Zhedanov. *Symmetry preserving quantization and self-similar potentials*, July 1995.

[CRM-2298] M. C. Delfour and J.-P. Zolésio. *Differential equations for linear shells: comparison between intrinsic and classical models*, July 1995.

[CRM-2299] M. C. Delfour and J.-P. Zolésio. *Shape analysis via distance functions* II, August 1995.

[CRM-2300] Y. Saint-Aubin. *Conformal invariance of a model of percolation on random lattices*, August 1995.

[CRM-2301] M. C. Delfour and J.-P. Zolésio. *Bounded total curvature sets*, August 1995.

[CRM-2302] M. C. Delfour and J.-P. Zolésio. *Curvatures and skeleton in shape optimization*, August 1995.

[CRM-2303] S. A. Campbell and J. Bélair. *Hopf bifurcation in a second order differential equation with delayed feedback*, August 1995.

[CRM-2304] M. C. Delfour and J.-P. Zolésio. *New intrinsic models for shells*, August 1995.

[CRM-2305] P. Winternitz. *Subalgebras of Lie algebras and their applications in physics*, August 1995.

[CRM-2306] A. M. Grundland and L. Lalague. *Invariant and partially invariant solutions of the equations describing a nonstationary and isentropic flow for an ideal and compressible fluid in (3+1) dimensions*, August 1995.

[CRM-2307] E. Montini and N. Schlomiuk. *Fonctions continues et fonctions continues à la Darboux: une approche historique*, August 1995.

[CRM-2308] D. Sankoff, J. Ehrlich and J. H. Nadeau. *Synteny conservation and chromosome rearrangements during mammalian evolution*, August 1995.

[CRM-2309] J. H. Nadeau, V. Ferretti and D. Sankoff. *Original synteny*, August 1995.

[CRM-2310] M. Blanchette, T. Kunisawa and D. Sankoff. *Parametric genome rearrangement*, August 1995.

[CRM-2311] A. H. Bougourzi and L. Vinet. *On the relation between $U_q(\widehat{sl(2)})$ vertex operators and q-zonal functions*, August 1995.

[CRM-2312] D. Levi and P. Winternitz. *Symmetries of discrete dynamical systems*, August 1995.

[CRM-2313] P. Mathieu and G. Watts. *Probing integrable perturbations of conformal theories using singular vectors*, August 1995.

[CRM-2314] G. M. Gandenberger, N. J. MacKay and G. W. T. Watts. *Twisted algebra R-matrices and S-matrices for affine toda solitons and their bound states*, August 1995.

[CRM-2315] A. Bensebah, F. Dubeau and J. Gélinas. *Numerical integration and A-stability of Galerkin methods for ordinary differential equations*, Sept. 1995.

[CRM-2316] F. H. Clarke, Y. S. Ledyaev and M. L. Radulescu. *Approximate invariance and differential inclusions in Hilbert spaces*, Sept. 1995.

[CRM-2317] D. Levi, L. Vinet and P. Winternitz. *Lie group formalism for difference equations*, Sept. 1995.

[CRM-2318] R. J. Stern. *Fixed points and zeros of multifunctions in non-Lipschitzian sets*, Sept. 1995.

[CRM-2319] G. Yang, M. C. Delfour and M. Fortin. *Uniformly convergent mixed finite elements for cylindrical shells*, Sept. 1995.

[CRM-2320] S. Ayari and S. Dubuc. *La formule de Cauchy sur la longueur d'une courbe*, Oct. 1995.

[CRM-2321] C. D. Horvarth and M. Lassonde. *Intersection of sets with n-connected unions*, Oct. 1995.

[CRM-2322] E. N. Derun, A. A. Kolyshkin and R. Vaillancourt. *Interaction of phase-shifted fields of two single-turn coils situated above a conducting medium*, Oct. 1995.

[CRM-2323] M. A. Abdelmalek, X. Leng, J. Patera and P. Winternitz. *Grading refinements in the contractions of Lie algebras and their invariants*, Oct. 1995.

[CRM-2324] R. Floreanini, J. LeTourneux and L. Vinet. *A q-deformed $e(4)$ and continuous q-Jacobi polynomials*, Nov. 1995.

[CRM-2325] Y. Berest. *Lacunae of hyperbolic Riesz' kernel and commutative rings of partial differential operator*, Nov. 1995.

[CRM-2326] G. Yang, L. C. Dutto and M. Fortin. *Inexact block Jacobi-Broyden methods for solving nonlinear systems of equations*, Dec.. 1995.

[CRM-2327] A. A. Izmest'ev, G. S. Pogosyan, A. N. Sissakian and P. Winternitz. *Contractions of Lie algebras and separation of variables*, Dec.. 1995.

[CRM-2328] J.-P. Gazeau and V. Spiridonov. *Toward the discrete wavelets with irrational scaling factor*, Dec.. 1995.

[CRM-2329] F. Perron. *On a conjecture of Krishnamoorthy and Gupta*, Jan. 1996.

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[CRM-2331] B. Mirandette. *Problèmes non linéaires pour des systèmes d'équations différentielles avec condition initiale ou périodique*, Jan. 1996.

[CRM-2332] J. C. Hurtubise. *Moduli spaces and particle spaces*, Jan. 1996.

[CRM-2333] J. C. Hurtubise. *Some algebraic geometry of integrable systems*, Jan. 1996.

[CRM-2334] M. A. Ayari and V. Hussin. *Computations of Lie supersymmetries for Grassmann-valued differential equations*, Feb. 1996.

[CRM-2335] J.-M. Lina. *Image processing with complex Daubechies wavelets*, Feb. 1996.

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[CRM-2337] A. Qaddouri, R. Roy, M. Mayrand and B. Goulard. *Collision probability calculation and multigroup flux solvers using PVM*, Feb. 1996.

[CRM-2338] M. R. Adams, J. Harnad and J. Hurtubise. *Darboux coordinates on coadjoint orbits of Lie algebras*, Feb. 1996.

[CRM-2339] A. A. Kolyshkin and R. Vaillancourt. *On the stability of convective flow between porous cylinders with radial flow*, Feb. 1996.

[CRM-2340] I. Julien and J. Bélair. *Analysis of a system of two coupled neural oscillators*, March 1996.

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[CRM-2343] S. Lafortune. *Superposition formulas for pseudo-orthogonal matrix Riccati equations and physical applications*, March 1996.

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[CRM-2348] M. Gamache, F. Soumis, G. Marquis and J. Desrosiers. *A column generation approach for large scale aircrew rostering problems*, May 1996.

[CRM-2349] F. Dubeau and J. Savoie. *On best error bounds for deficient splines*, May 1996.

[CRM-2350] F. Dubeau and J. Savoie. *More on the roots of Euler-Frobenius polynomials*, May 1996.

[CRM-2351] L. Olien and J. Bélair. *Bifurcations, stability, and monotonicity properties of a delayed neural network model*, May 1996.

[CRM-2352] J.-P. Gazeau and J. Patera. *Tau-wavelets of Haar*, August 1995.

[CRM-2353] L. Chen, R. V. Moody and J. Patera. *Non-crystallographic root systems*, May 1996.

[CRM-2354] S. Grimm. *On orbit sum values of elements of finite order*, May 1996.

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[CRM-2359] Y. Y. Berest. *Solution of a restricted Hadamard's problem in Minkowski spaces*, May 1996.

[CRM-2360] L. Lapointe and L. Vinet, *A short proof of the integrality of the Macdonald (q,t)-Kostka coefficients*, May 1996.

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[CRM-2364] S. Kallel and R. J. Milgram, *The geometry of the space of holomorphic maps from a Riemann surface to a complex projective space*, December 1995.

[CRM-2365] B. Krauskopf and C. Rousseau, *Codimension-three unfoldings of reflectionally symmetric planar vector fields*, May 1996.

[CRM-2366] F. Dumortier, M. El Morsalani, and C. Rousseau, *Hilbert's 16th problem for quadratic systems and cyclicity of elementary graphics*, September 1995.

[CRM-2367] P. Mardešić, L. Moser-Jauslin, and C. Rousseau, *Darboux linearization and isochronous centres with a rational first integral*, October 1995.

[CRM-2370] S. Dubois and D. Sankoff, *Disclosure enumerators and Schegloff's denominators*, 1996.

[CRM-2388] F. H. Clarke, Yu. Ledyaev, R. Sontag, and A. I. Subbotin, *Asymptotic controllability implies feedback stabilization*, 1996.

[CRM-2390] F. H. Clarke, *Generalized solutions of the Hamilton-Jacobi equation: A survey*, 1996.

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[CRM-2393] A. Luong and L. G. Doray, *Efficient estimators for the good family*, 1996.

[CRM-2394] L. G. Doray, *A semiparametric estimator of the IBNR reserve*, 1996.

[CRM-2395] J. Mahaffy, J. Bélair, and M. Mackey, *Hematopoietic model with moving boundary condition and state dependent delay*, 1996.

[CRM-2396] C. Rustom and J. Bélair, *Estimation numérique de la vitesse de décroissance des spectres de puissance*, 1996.

[CRM-2397] E. Shahbazian, *Feasibility study on sensor data fusion for the CP-140 aircraft—fusion architecture analyses*, July 1995.

[CRM-2398] M. Frigon, *On a critical point theory for multivalued functionals and applications to partial differential inclusions*, 1996.

[CRM-2399] M. Frigon, *On continuation methods for contractive and nonexpansive mappings*, 1995.

[CRM-2400] T. Hikita and I. G. Rosenberg, *Completeness for uniformly delayed circuits, a survey*, 1995.

[CRM-2401] I. G. Rosenberg, *Wall monoids I*, October 1995.

[CRM-2402] I. Chajda, G. Czédli, and I. G. Rosenberg, *Kernels of tolerance relations*, 1996.

[CRM-2403] G. Pogosyan, M. Miyakawa, A. Nozaki, and I. G. Rosenberg, *On the number of clique Boolean functions*, 1996.

[CRM-2404] I. G. Rosenberg, *Hypergroups induced by paths of a directed graph*, 1996.

[CRM-2405] I. G. Rosenberg, *Sur les tolérances d'une algèbre*, 1995.

[CRM-2406] M. Lemire and S. Lessard, *On the nonexistence of an optimal migration rate*, 1995.

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[CRM-2412] J. A. Toth, *Eigenfunction localization in the quantized rigid body*, 1996.

[CRM-2413] Y. G. Yatracos, *A small sample optimality property of the MLE*, 1996.

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[CRM-2415] Y. G. Yatracos, *Assessing the accuracy of bootstrap samples*, 1996.

[CRM-2416] Y. G. Yatracos, *Variance, clustering and identification of high leverage points*, 1996.

[CRM-2417] D. Dufresne, *On a property of gamma distributions*, 1995.

[CRM-2418] D. Dufresne, *On an identity due to Bourgerol*, 1995.

[CRM-2419] C. M. Van Vliet and A. Huisso, *New noise problems in an old form: 'recycling' fluctuation phenomena*, July 1995.

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[CRM-2421] D. Dufresne, *From compound interest to Asian options*, 1996.

[CRM-2422] N. S. Altman and Brenda MacGibbon, *Consistent bandwidth selection for kernel binary regression*, 1996.

[CRM-2424] J. Patera, *Non-crystallographic root systems and quasicrystals*, 1996.

[CRM-2425] S. Grimm and J. Patera, *Decomposition of tensor products of the fundamental representation of* e_8, 1996.

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[CRM-2428] L. Gagnon and F. Drissi-Smaili, *Speckle reduction of airborne SAR images with symmetric Daubechies wavelets*, 1996.

[CRM-2429] D. Dufresne, *On the stochastic equation* $L(x) = L[b(x+c)]$ *and a property of gamma distributions*, 1996.

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[CRM-2431] C. M. Van Vliet and R. Srunivasan, *Quantum transport and noise in the transition from mesoscopic to ballistic devices*, 1996

[CRM-2432] C. M. Van Vliet, *Gigahertz nonequilibrium noise in mesoscopic conductors*, 1996

[CRM-2433] F. Benamira and C. M. Van Vliet, *Landauer's multichannel conductance formula: Linear response-theory approach*, 1996

[CRM-2434] C. M. Van Vliet, *Quantum transport in solids*, 1996

[CRM-2435] C. M. Van Vliet, *Nonequilibrium noise from LF to terahertz range in mesoscopic and ballistic quasi-1D conductors*, 1996

[CRM-2436] A. H. Marshak and C. M. Van Vliet, *Semiclassical current explosions for materials with position-dependent band structure in the near equilibrium approximation*, 1996

FINANCIAL REPORT

The fiscal year of the CRM starts on June 1 and ends on May 31. The Financial Statement presents, on a cash-flow basis, the major expenses and income of the CRM during 1995-1996, as well as its financial position at the beginning and at the end of the period. The overall results have been broken down into three columns representing the following sources of financing: the Natural Sciences and Engineering Research Council of Canada (NSERC), the Fonds pour la formation de chercheurs et l'aide à la recherche du Québec (FCAR), and Other sources.

During 1995-1996 the CRM has received INCOME (presented at the bottom of the Statement) from the following sources. ***NSERC***: $750,000 in the form of an operating grant to pursue its national mandate, and $75,000 to jointly develop the National Computer Network for Mathematical Research (NCNMR) with the Fields Institute of Toronto and the Pacific Institute for the Mathematical Sciences (PIms) (see Note 1 to the Financial Statement); ***FCAR***: $170,500 in an operating grant from its Research Centre program; ***Other sources***: a substantial grant of $771,300 has been received from the Comité d'étude et d'administration de la recherche (CEDAR) of the Vice-rectorat à la recherche of the Université de Montréal (in addition to office space, heating, electricity, etc.); other important sources of income include the Canadian Institute for Advanced Research (CIAR), the McConnell Foundation, and Dr. André Aisenstadt who is the CRM's major benefactor; finally, the CRM earns revenues from books in the CRM series published by the American Mathematical Society (AMS) and in its own in-house publication program, as well as from registration fees charged for attending scientific activities.

Major Sources of Revenue in 1995-96

Université de Montréal*	771 300
NSERC	775 000
FCAR	170 500
CIAR	74 475

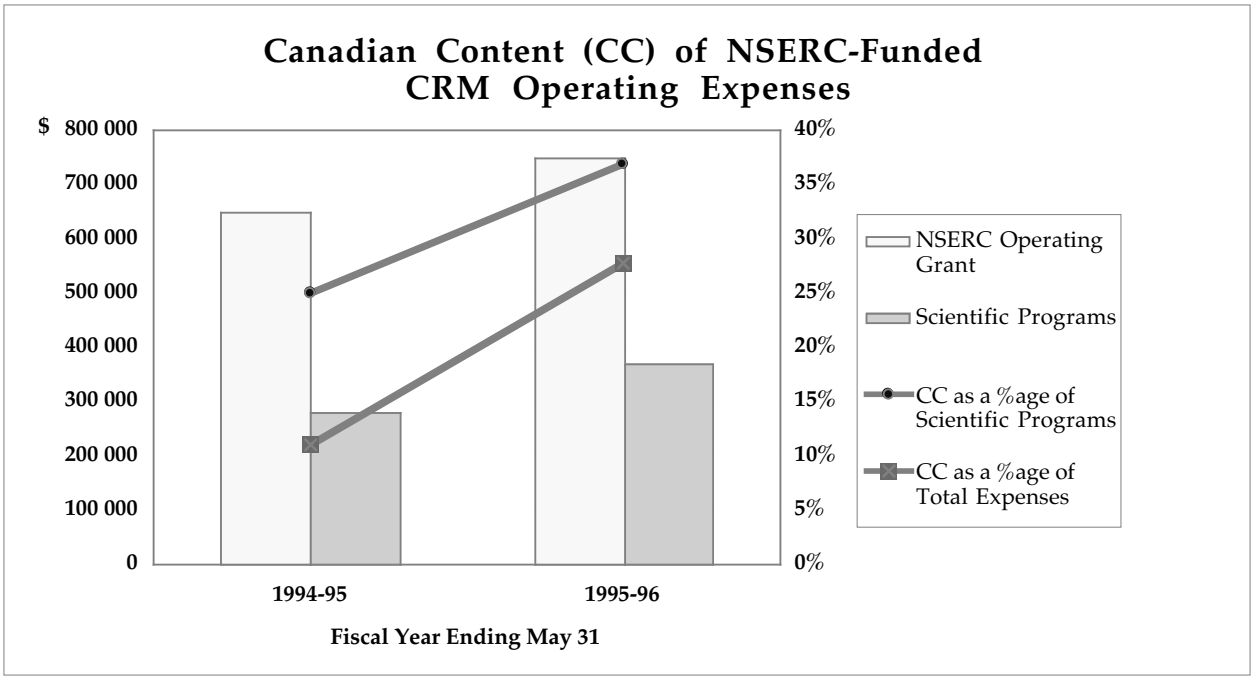
* In addition, the UdeM provides office space, heating, electricity, etc.

The EXPENSES of the CRM are presented under three major categories: Scientific Personnel, Scientific Programs, and Administration. Major items under ***Scientific Personnel*** include the remuneration of Université de Montréal professors who do research while in residence at the CRM, of postdoctoral researchers, expenses associated with the detachment of professors so that they can work at the CRM, and expenses associated with three prizes for excellence in the mathematical sciences: the CRM-Fields Institute Prize, the André-Aisenstadt Prize and the Canadian Association of Physicists (CAP)-CRM Prize. The ***Scientific Programs*** include expenses related to the 1995-1996 theme year in Numerical and Applied Analysis, as well as some expenses from the previous theme year (Geometry and Topology) and the next theme year (Combinatorics and Group Theory); the Banff Summer School of 1995 related to the theme year in Numerical and Applied Analysis, as well as the advance payment on the 1996 Summer School; the General Scientific Program, mainly constituted of contributions of the CRM to off-site scientific activities; the Colloquia and Seminar Series organized jointly with the Montréal-based Institut des Sciences Mathématiques (ISM); and a Discretionary Fund used to finance unanticipated events the CRM deemed worthy of support during the year. Finally, the ***Administration*** portion of the Statement include: the remuneration of the staff (Director's Office, Administration and Services to Researchers, Scientific Activities, Publications and Computer Systems); the expenses related to the meetings of the Advisory Committee and CRM-Fields Institute Coordinating Committee; miscellaneous operating expenses; and computer equipment and maintenance expenses.

The NATIONAL MANDATE of the CRM is reflected in the NSERC column of the Statement labelled as *Canadian*. Under this heading are singled out those NSERC-funded expenditures of the CRM which occurred in Canada, but outside of Québec. Such expenses include the Summer School in Banff, numerous off-site scientific events sponsored by the CRM (often in collaboration with the Fields Institute), and the expenses related to non-Québec Canadians visiting the CRM in order to participate in its scientific programs. The ratio of such *Canadian* expenses to the overall NSERC-funded expenses is: 37% for the Scientific Programs only, and 28% for the total expenses funded by NSERC (i.e. including the portion of the Prizes and Adminis-

tration expenses related exclusively to the *Canadian* operations of the CRM). This ratio of 28% is well above the threshold of 25% suggested by the CRM-Fields Institute Coordinating Committee in its latest report.

Concerning our RESULTS AND FINANCIAL POSITION, the CRM has recorded a minor overall deficit of $ 3,588 during the period, which has reduced its financial cushion from $ 111,323 at the beginning of the period to $ 107,736 at the end (a cushion representing less than 6% of its total expenses for the year). The detailed results show that major accounts have been brought closer to equilibrium during the year. A surplus of $ 75,872 for the period has brought the CRM's NSERC-account accumulated deficit from $ 79,176 to $ 3,304. A surplus of $ 25,054 for the period has brought the CRM's FCAR-account accumulated position from a $ 14,171 deficit to a $ 10,883 surplus. Finally, a deficit of $ 104,514 for the period has brought the CRM's other-account accumulated surplus down from $ 204,670 to $ 100,156.



Financial Statement

	NSERC		FCAR	OTHER	TOTAL
Scientific Personnel	**Total**	**Canadian**			
Salaries				645 557	645 557
Chairs					
Partnerships	18 750			5 000	23 750
Release Time	1 983			21 884	23 867
Research Fellows					
Postdoctoral Researchers					
• CRM	27 011		9 661		36 672
• CRM/ISM	51 185			- 2 915	48 270
• CERCA/CRM	63 104				63 104
• GERAD/CRM	14 000				14 000
- Research Grants					
Prizes	12 265	11 075		7 425	19 690
Summer Students and Other					
Subtotal	188 297	11 075	9 661	676 951	874 910
Scientific Programs					
Geometry and Topology	7 502	1 159		12 234	19 736
Numerical and Applied Analysis	178 385	11 841		15 979	194 365
Combinatorics and Group Theory	18 806			- 150	18 656
Summer School of 1995	66 291	66 291		- 5 431	60 860
Summer School of 1996	4 067	4 067			4 067
Scientific Program - General	58 203	44 435		- 2 921	55 281
Colloquia and Seminar Series	5 069	2 154		2 600	7 669
Discretionary Fund	29 779	5 983		939	30 717
Subtotal	368 101	135 930		23 249	391 350
Administration		37%			
Personnel	103 922	38 376	136 501	249 391	489 814
Advisory Committee	3 297	2 782		516	3 813
CRM/Fields Coordinating Committee	5 870	5 870		539	6 409
Miscellaneous	21 176	601	- 821	52 878	73 234
Computer Equipment	8 464		104	15 684	24 252
Subtotal	142 730	47 628	135 785	319 008	597 523
TOTAL	**699 128**	**194 634**	**145 446**	**1 019 208**	**1 863 782**
Income		28%			
Operating Grants (1)	775 000		170 500	895 308	1 840 808
Equipment Grants					
Sales and Contributions				19 386	19 386
Total	**775 000**		**170 500**	**914 695**	**1 860 195**
Surplus (Deficit)	**75 872**	**N \ A**	**25 054**	**- 104 514**	**- 3 588**

Cash at the beginning of the period	**- 79 176**		**- 14 171**	**204 670**	**111 323**
Cash at the end of the period	**- 3 304**		**10 883**	**100 156**	**107 736**

(1) The CRM obtained $ 825,000 from NSERC: $ 750,000 in an operating grant, and $ 75,000 in a grant for the National Computer Network for Mathematical Research. However, $ 50,000 have been deducted from the latter amount because each of the Fields and PIms institutes were owed $ 25,000 for their share in the development of the Network.